WIN a trip to Kennedy Space Center and train like an astronaut! *For details see page 16*

Astronomy

August 2009

The world's best-selling astronomy magazine®

SPECIAL REPORT

COUNTDOWN TO 2020

Return to the Moon

Get the inside story on how humans will set off on the greatest adventure ever p. 24

Apollo 11 landed here

Next step Mars? p. 30

Europe's Moon mission revealed p. 44

Asia's new assault on the Moon p. 50

PLUS

Who was the real Charles Messier? p. 54

Orion's new truss-tube scope field-tested p. 58

Bob Berman on the edges of the universe p. 14

www.Astronomy.com

$5.95

0 72246 46770 1 08

Vol. 37 • Issue 8

Some Holes Just Need to be Filled!

The new 10mm Ethos has landed at your Tele Vue dealer! It slots right between the 8 and 13mm models making it ideal for all types of scopes, especially 8" SCTs, and it's everything you love about the Ethos series.

"★★★★★ Sensibly perfect. No meaningful improvements possible. The Ethos hasn't sacrificed one bit of on-axis performance."
— Dennis Di Cicco, *Sky & Telescope*

"100° Field of View combined with amazing clarity and pinpoint definition is like putting an IMAX in your telescope."
— Vic Menard, *Astronomy Technology Today*

"Like Alice, I had gone through the looking glass and entered a new world of visual wonder."
— Stephen James O'Meara, *Astronomy*

"Ethos is a stunning achievement that sets a new standard in wide-field eyepieces."
— Tom Trusock, *BBC At Night.*

"The Ethos provides an amazing 100° Field of View that has to be seen to be believed. The eyepiece truly gets out of the way for the ultimate spacewalk experience. Star images are pinpoint right to the edge and contrast is superb. If you want the best, this is it." — Dickenson & Dyer, *The Backyard Astronomer's Guide*

Model:	6mm Ethos	8mm Ethos	10mm Ethos	13mm Ethos	17mm Ethos
Apparent FoV.	100°	100°	100°	100°	100°
Eyerelief:	15.0mm	15.0mm	15.0mm	15.0mm	15.0mm
Field Stop Dia.:	10.4mm	13.9mm	17.7mm	22.3mm	29.6mm
Weight:	15.5 oz.	15.2 oz.	17.9 oz.	20.8 oz.	24.8 oz.

Tele Vue® Visionary

32 Elkay Drive, Chester, New York 10918 845.469.4551 www.TeleVue.com

astronomics™

The optical center of the known Universe.™

Anyone can sell you a telescope.
We'll sell you the right telescope.™

At *astronomics,* our family business has helped people choose the right telescope since 1979. (That's one of our third generation of astronomers to the right getting up-close and personal with a telescope.) Our friendly people have *over 150 years of experience using and selling telescopes,* so we have the knowledge to help *you* pick the scope and accessories that best fit your needs (and budget).

astronomics. Honest advice from telescope experts, the time to make sure you get the right telescope, and good prices you can afford. Call us toll-free at (800) 422-7876 and see for yourself.

A best-buy Celestron NexStar SE go-to just got $100 to $200 better!

The Celestron NexStar SE 4" to 8" go-to telescopes are known as four of the best values in backyard astronomy. Now, at their new lower prices, *the Celestron NexStars are better values than ever before!*

Many of the advanced features in a Celestron NexStar SE were unavailable at *any* price only a few short years ago. For example, their *SkyAlign* go-to computers make astronomy as easy as 1-2-3. Just point your NexStar at three bright stars and it automatically lines up on the sky so it can find *40,000+* celestial objects for you. It only takes a minute or two and you don't even have to know which star is which!

And the Starbright XLT multicoatings on each NexStar SE give you the brightest images and highest contrast ever, so you can see more, and see it better! ~~was $999~~ **now $799!**

The Celestron NexStar SE – *clearly better than ever!*

NexStar 4 SE, *was $599, now* ... **$499**
NexStar 5 SE, *was $799, now* **699**
NexStar 6 SE, *was $999, now* **799**
NexStar 8 SE, *was $1399, now* .. **1199**

A *premium* 8" Astro-Tech Ritchey-Chrétien, $1395. Surprised?

You shouldn't be. More premium performance for less money is standard equipment with Astro-Tech.

A Ritchey-Chrétien has long been the astrograph of choice for serious astro-imagers. But up until now, an R-C cost a fortune. No longer!

The **Astro-Tech AT8RC** is the *first* sensibly-priced 8" R-C from a U. S. supplier. It has premium features the competition doesn't offer, like mirrors of *low thermal expansion quartz* (not ordinary optical glass) and a body of *low expansion carbon fiber* (not metal) to minimize any temperature-induced focus changes. For maximum light transmission, it has *99% reflectivity dielectric mirror coatings* rather than the conventional lower-reflectivity aluminum coatings others use. Ideal for large format (STL-type) CCDs with long equipment trains, the AT8RC costs only **$1395**

Want something a little smaller, a little lighter, *and $600 lower in price?* The 6" **Astro-Tech AT6RC** is a *Hot Product for 2009.* One owner wrote us to say "I cannot believe how good a scope one gets for such a low price. Great value." Ideal for imaging with webcams, DSLRs, and Deep Sky Imager-type cameras, the AT6RC is a steal at **$795**

The Meade ETX-LS – now SC *or* ACF.

SCT, **$1299**
ACF, **$1499**

You now have your choice of either time-tested Schmidt-Cassegrain (SC) optics *or* Advanced Coma-Free (ACF) optics when you get the 6" go-to **Meade ETX-LS**.

Meade catadioptric ACF optics deliver the same sharp coma-free views as a Ritchey-Chrétien telescope, but without an R-C's high price tag.

Innovative LightSwitch and Level North Technology, GPS, and a CCD camera under the optical tube provide the only automatic no-hands eyes-closed sky alignment available in *any* consumer scope.

The CCD camera has its own lens and stores 8° wide-field vistas on an optional SD card. View them on your computer later or see them immediately using the ETX-LS video output and an optional monitor.

And ETX-LS Astronomer-Inside software guides you to the best objects in the night sky while a built-in speaker takes you on a guided tour of hundreds of night sky objects.

ETX-LS. *Astronomy made easy.*

Save 10% to 15% on TeleVue – even more if you're a Cloudy Nights member.

The **TeleVue eyepiece** sale saves you *15% or more.*

How do you get *"or more"* eyepiece savings? Simple. Go online to **www.cloudynights.com/register** and join Cloudy Nights *for free.*

~~$620~~ **$560**

Once you join Cloudy Nights, you get extra discounts on almost everything you buy from Astronomics.

Cloudy Nights is the biggest and friendliest online astronomy community. It has unbiased equipment reviews by observers just like you, and its forums are filled with helpful chats and advice from thousands of fellow astronomers on how to use your scope and accessories.

Here are sale prices on a few of the TeleVue eyepieces we stock – *before your Cloudy Nights discount:*

Plössls – *you save $10* **$75**
Radians – *you save $25* **225**
Nagler Type 6 – *you save $30* **260**
31mm Nagler – *you save $65* **575**

And *you save 15%* on **TeleVue refractors.** Here are some examples:

TV-60 – *you save $123* **$701**
TV-85 – *you save $322* **1827**
NP-101 – *you save $552* **3131**
NP-127is – *you save $1047* **5937**

A "really sweet grab-and-go" Astro-Tech mount.

A magazine review said the $299 **Astro-Tech Voyager** altazimuth mount was "unusually stable for its size and weight" and packed "lots of first-class engineering" that made it "a really sweet grab-and-go setup that's ideal for viewing day or night."

The easy to transport and set up Astro-Tech Voyager weighs only 15 pounds, yet holds a full 20 pound payload with ease. It has automatic clutch dual worm gear manual slow motion controls, an adjustable height aluminum tripod, a Vixen-style dovetail, and a very affordable Astro-Tech price.

A Lunt scope can feature very prominently in your prominence observing.

As we enter the active phase of the solar cycle, this affordable 60mm Lunt H-alpha scope is sure to become your favorite for serious solar observing for years to come. Its sharp <0.8 Ångstrom passband H-alpha filter shows spectacular prominences and high contrast disk details with any 1.25" eyepiece.

99% reflectivity *dielectric* diagonals start at $69.95.

The **Astro-Tech 1.25" diagonal**, just like Astro-Tech's 2" star diagonals, has a compression ring eyepiece holder, 46-layer *dielectric* coatings, and a premium 1/10th wave BK7 optical glass mirror substrate.

$69.95

In addition to 99% reflectivity, the very smooth ion-deposited dielectric coatings improve your lunar and planetary contrast. Astro-Tech 2" BK7 dielectrics start at $119.95, while 2" quartz dielectrics start at $189.95.

Cloudy Nights is the *official* astronomy forums of the *International Year of Astronomy 2009.*

Get equipment discounts at astronomics by joining Cloudy Nights *free* at www.cloudynights.com/register.

The Celestron SkyScout IYA is only $199.

The **Celestron SkyScout** International Year of Astronomy edition non-magnifying hand-held personal planetarium uses GPS to locate and identify 50,000 sky objects, including every one you can spot by eye.

$199

Earbuds tell you their stories or you can read them on the scrolling 5-line text and graphics display. This IYA edition has unique content available nowhere else.

Are you a sky watcher now, or is a Sky-Watcher in your future?

Whether you have a small scope and want something bigger, or want to jump right into observing with a big scope, there's a feature-laden Sky-Watcher Dob in your future.

Their telescoping truss tubes make them easy to transport. Their sensible prices make them easy to afford.

astronomics™

Our 30th year of friendly service, reliable advice, and money-saving prices.

680 24th Avenue SW, Norman, OK 73069 **PHONE HOURS: 8 to 8 CST Mon - Fri, Sat 12 to 5.** **STORE HOURS: 9 to 5 Mon - Fri, Sat by appointment.**

Toll-Free Telephone: **(800) 422-7876** On the web at: **www.astronomics.com**

24-Hour FAX line: **(405) 447-3337** Our e-mail address: **questions@astronomics.com**

Prices, special offers, and specifications are current as of 5/1/09, but are subject to change.

Mastercard, Visa, Discover, American Express.

ORION® TELESCOPES & BINOCULARS Since 1975

Your Affordable Astro-Imaging Source

TELESCOPES | ACCESSORIES | ASTRO-IMAGING | MICROSCOPES | BINOCULARS | SHOP BY BRAND | GIFT CENTER

IMAGING TELESCOPES

New!

Orion® 8" F/8 Ritchey-Chrétien Astrograph Telescope

$1,195.95

#08958

M17, Swan Nebula – Orion Image

IMAGING CAMERAS

Orion® StarShoot™ Pro V2.0 Deep Space Color CCD

$1,399.95

#52085

Leo Trio – Orion Image

IMAGING ACCESSORIES

New!

Orion® SteadyPix™ Deluxe Camera Mount

$44.95

#05338

IC5070, Pelican Nebula – Orion Image

IMAGING ACCESSORIES

New!

Orion® Deluxe Off-Axis Guider

$109.95

#05521

NGC 2264 Nebula Complex – Orion Image

IMAGING FILTERS

Orion® 2" SkyGlow™ Astro-Imaging Filter

$165.95

#05561

M3, Globular Cluster – Orion Image

IMAGING ACCESSORIES

New!

Orion® StarShoot Solitaire™ AutoGuider

$599.95

#52074

IC5146, Cocoon Nebula – Orion Image

THE ULTIMATE IN ASTRONOMY SHOPPING:
www.adorama.com

FREE Shipping
ON THOUSANDS OF PRODUCTS
SEE OUR WEB SITE

MEADE

LX90-ACF SERIES

**The Meade 8, 10, & 12"
LX90 Advanced Coma-Free**

Includes: with MgF2 coatings on the correcting lens and standard aluminum coatings on the primary and secondary mirrors
(Ultra-High Transmission Coatings included)

Camera Adaptable

LEVEL NORTH™ TECHNOLOGY

KEY FEATURES
- GPS & Level North Technology
- Smart Drive, Autostar Controller
- Oversize Primary Mirror, Diffraction - Limited Optics
- Rigid Cast Aluminum Fork Mount
- LX-200 Series Tripods
- Smart Finder (Red Dot) & 8x50 View Finder
- AutoStar Suite Astronomer's Edition Software

LX90	Price
8" w/UHTC	$2,099.00
10" w/UHTC	$2,799.00
12" w/UHTC	$3,399.00

MEADE ETX-LS LIGHTSWITCH

KEY FEATURES
The revolutionary ETX-LS astronomical telescope features the most advanced electronics and optics ever applied to a consumer telescope. Meade is producing the easiest-to-use, most entertaining, educational, highperformance telescope on the market by combining LightSwitch Technology, Advanced Coma Free Optics™ (ACF™), Astronomer Inside™ multimedia output and a completely new mechanical design

LightSwitch Technology:
Alignment system for completely hands free alignment. Using the Integrated Sensor Module and the built-in ECLIPS CCD imager on the telescope tube, our LightSwitch Technology allows the telescope to completely align itself with the sky without any input from the user. The user simply flips the LightSwitch on and the telescope finds its location, time, date, north, level, then locates and centers the alignment stars for a perfect alignment every time without user input.

NEW

Camera Adaptable

6" ETX-LS **$1299.00**

EXPLORE SCIENTIFIC

The David H. Levy

Comet Hunter™ Special Edition Telescope
The Comet Hunter comes standard with a two-inch, 30mm focal length eyepiece with a wide 70° apparent field. This eyepiece combined with the short focal length of the telescope produce an amazing 2.86 ° true field of view with a 6.2mm exit pupil.

Sky-Watcher

SW 90-MAK-MultiMount,

- 90mm Maksutov-Cassegrain Telescope
- 1250mm Focal Length.
- 8 x 20 Finder Scope,
- Tabletop Tripod
- L-Bracket
- Two Premium 4-Element 1.25" Super Plossl Eyepieces
- Image-Erect 90° Roof-Prism
- Handy, Attractive Backpack
- Skywatcher Warranty

SPRING SPECIALS
BIG DISCOUNTS
Call or Email for Price

MEADE · CORONADO · STAR-BOUND · ZEISS · SBIG · Starry Night · TELRAD · Thousand Oaks Optical · RIGEL SYSTEMS · tasco · LUMICON · KNIGHTWARE · SOFTWARE BISQUE · Leica · SWAROVSKI OPTIK · KENDRICK ASTRO INSTRUMENTS

CORONADO

PST, SolarMax 40 Telescopes, 60 & 90mm systems

New Lower PRICES

Check Our Web Site for a Full Listing

ORION TELESCOPES & BINOCULARS

Check Our Web Site for a Full Listing

PROOPTIC

MIRROR DIAGONALS
- **INCREASES BRIGHTNESS**
- **IMPROVES CONTRAST**

90° Mirror Star Diagonals with Dielectric coatings provides over 99% reflectivity.

FEATURES
COATING.....Dielectric
REFLECTIVITY.....99 %
FINISH.....Anodizing
COLOR.....Black
HOUSING MATERIAL .....Aluminum
With eyepiece locking collar
2" Diagonals includes
2"-1.25" Adapter

EXTENDED SPECIAL PRICING

1.25"	#PROD1	~~$69.95~~	$59.95
2"	#PROD2	~~$129.95~~	$99.95
2" SCT Thread	#PROD2S	~~$129.95~~	$109.95

NEW! Pro Optic Long Eye Relief Eyepieces

The LER eyepieces are designed for excellent Lunar, Planetary, Double Star and Deep Sky viewing. They feature 20mm Eye Relief, Fully Multi-Coated lens, Parfocal, 55 Degree Apparent field of view, Rubber Eyeguards, Grip Rings and are threaded for filters

PRO3LER	3mm LER 1.25"
PRO5LER	5mm LER 1.25"
PRO6LER	6mm LER 1.25"
PRO9LER	9mm LER 1.25"
PRO125LER	12.5mm LER 1.25"
PRO145LER	14.5mm LER 1.25"
PRO18LER	18mm LER 1.25"

EXTENDED SPECIAL PRICING
$79.99
Regular Price ~~99.95~~

Tele Vue®

Adorama's 20th Year Proudly Selling Tele Vue

RADIAN EYEPIECES
60° FIELD
20mm Eye-Relief

PLOSSL EYEPIECES
Modest Price With Extraordinary Performance!

Vixen Optics

R200SS OTA

The remarkably fast 200mm (8") f/4 parabolic primary mirror of the Vixen R200SS Newtonian reflector gives extremely sharp images with no chromatic aberration. The use of state-of-the-art coating technology yields the ideal surface for its f/4 primary mirror. The visual observer will enjoy wide views of deep sky objects. Actual groups of nebula or clusters can be viewed at the same time with this instrument.

SPECIFICATIONS:
Optical tube .....200mm Parabolic, Multi Coated, Newtonian OTA
Focal Length / F# 800mm F/4
Highest Useful Magnification.....400x
Limiting Stellar Magnitude 13.3
Resolution Rayleigh.....Resolving power 0.63"
Light Gathering Power.....816x

SHIPPING INSTRUCTIONS See Our Web Site WWW.ADORAMA.COM For Shipping Charges And Relevant Information.

ADORAMA INC.
Source for the **Educated Photographer**
42 West 18th Street New York, N.Y. 10011 info@adorama.com
www.adorama.com • Order Toll Free USA / Canada **800-223-2500**
Orders & Information - **212-741-0052**

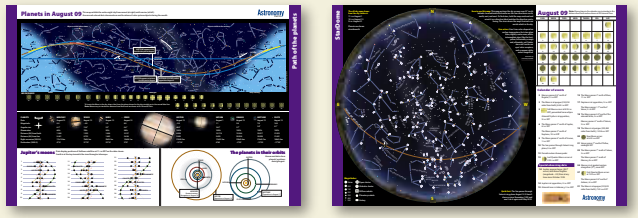
VOL. 37, NO. 8

Astronomy

The world's best-selling astronomy magazine

August 09

CENTER PULLOUT



Path of the planets and StarDome.

WIN a trip to Kennedy Space Center and train like an astronaut! For details see page 16
Astronomy
SPECIAL REPORT
COUNTDOWN TO 2020
Return to the Moon
Next step Mars?
Europe's Moon mission revealed
Asia's new assault on the Moon
PLUS

Cover: NASA

ON THE COVER

Forty years after Apollo 11 astronauts landed on the Moon, NASA is developing the equipment to take us back. The next generation of lunar exploration could begin as early as 2020.

8 This Month in *Astronomy*
Looking back and looking ahead.

10 Astro Confidential
Andrea Ghez, Dragan Huterer, Joan Najita, Adam Riess, Frank Shu

12 Letters
The power of your eyes.

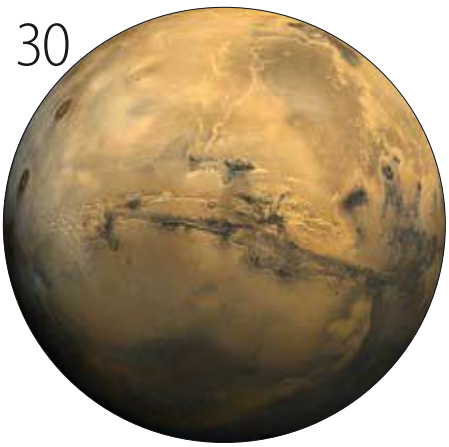
13 Web Talk

14 Strange Universe
Edges of the universe. **BOB BERMAN**

15 Observing Basics
Double the observing fun. **GLENN CHAPLE**

18 Astro News
New survey reveals cosmic structure.
Dawn of a new day.
A near-Earth-sized exoplanet discovered.

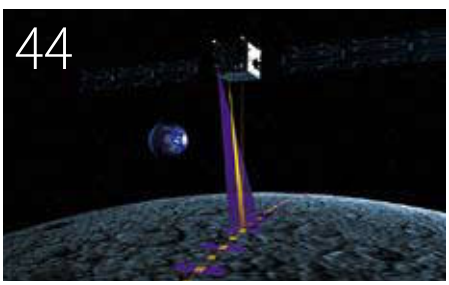
30



COVER STORY

24 How we'll return to the Moon
Four decades after the first human landing, we stand on the threshold of a second grand adventure. **JAMES OBERG**

44



54

30 Next step Mars?
Landing humans on the Red Planet is harder and more dangerous than you might think, but it can be done. Here's how. **DANIEL PENDICK**

36 The Sky this Month
Jupiter reaches its peak. **MARTIN RATCLIFFE AND ALISTER LING**

44 What Europe's Moon mission revealed
Lead Project Scientist Bernard H. Foing explains how SMART-1 served as a steppingstone for future solar system exploration. **BERNARD H. FOING**

48 Ask Astro
What sculpts nebular shapes?

50 Asia's new assault on the Moon
First-ever lunar missions from Japan and China returned valuable data and laid the foundation for more ambitious exploration. **MICHAEL E. BAKICH**

54 Who was the real Charles Messier?
His catalog of deep-sky objects may be world famous, but most people don't know much about the man behind it. **RONALD STOYAN**

58 Orion's truss-tube scope offers power and portability
With the help of the SkyQuest XX12 reflector, finding faint deep-sky treats just got easier. **PHIL HARRINGTON**

60 Evening Stars
A great's life. **DAVID H. LEVY**

62 Secret Sky
Moonbows: architecture of light. **STEPHEN JAMES O'MEARA**

64 New Products

68 Advertiser Index

69 The Cosmic Grid

70 Reader Gallery

WEB EXTRA

Visit **Astronomy.com/toc** for bonus material — it's exclusive to *Astronomy* magazine subscribers. Check out the new Astronomy.com today.

Astronomy (ISSN 0091-6358, USPS 531-350) is published monthly by Kalmbach Publishing Co., 21027 Crossroads Circle, P. O. Box 1612, Waukesha, WI 53187–1612. Periodicals postage paid at Waukesha, WI, and additional offices. POSTMASTER: Send address changes to *Astronomy*, 21027 Crossroads Circle, P. O. Box 1612, Waukesha, WI 53187–1612. Canada Publication Mail Agreement # 40010760.

CELESTRON® NexStar™ SE Series

ASTRONOMY MADE SIMPLE!

Who says Astronomy has to be complicated or even expensive for that matter? Celestron is proud to announce an incredible price reduction on our entire line of NexStar SE telescopes.

Let a NexStar SE help you find thousands of stars, planets, galaxies and more at the touch of a button! The NexStar SE family combines unprecedented ease of use with advanced features and incredible value.

Buyer's remorse not included.

- Series features a 4" Maksutov-Cassegrain optical design or the 5", 6" and 8" Schmidt-Cassegrain optical design
- Computerized hand control with nearly 40,000 object database and motorized Altazimuth mount
- StarBright XLT® enhanced coatings for maximum light transmission and clarity
- SkyAlign™ technology allows you to choose any three bright objects, for a fast and easy alignment process
- Flash upgradeable hand control; update your telescope's operating software via the internet
- All NexStar SE models are GPS compatible and come with an auxiliary port for use with additional accessories
- Internal battery compartment to prevent cord wrap during use
- Includes NexRemote® telescope control software, for advanced control of your telescope via computer
- "THE SKY®" Planetarium software – with 10,000 object database, printable sky maps and enhanced images
- For more information on the NexStar SE visit: **www.celestron.com/se**

1. SE telescopes feature Celestron's renowned optical systems and come standard with our premium StarBright® XLT Coatings.
2. Flash upgradeable hand control contains a database of nearly 40,000 celestial objects and advanced software features including SkyAlign, Identify Mode, User-definable Horizon Limits, and Precise GoTo.
3. Designed For Portability: with heaviest model only 24 lbs, spend more time observing with these lightweight and easy to set-up telescopes.

ITEM #	MODEL	PRICING
11049	NexStar 4SE **Reduced $100!**	Now Only $499*
11036	NexStar 5SE **Reduced $100!**	Now Only $699*
11068	NexStar 6SE **Reduced $200!**	Now Only $799*
11069	NexStar 8SE **Reduced $200!**	Now Only $1199*

*Price does not include shipping and tax.

CELESTRON PREMIER SELECT DEALER

- Adorama – 800.223.2500 – www.adorama.com
- OPT Corp. – 800.483.6287 – www.optcorp.com
- High Point Scientific – 800-266-9590 – www.highpointscientific.com
- Telescopes.com – 888.988.9876 – www.telescopes.com
- Scope City – 800.235.3344 – www.scopecity.com
- Astronomics – 800.422.7876 – www.astronomics.com
- Optics Planet – 800.504.5897 – www.opticsplanet.com

Price is suggested retail in U.S. Dollars. Pricing subject to change without notice.

Looking back and looking ahead

by David J. Eicher

I recall the evening of Sunday, July 20, 1969, very clearly. Huddled in our family's living room in Oxford, Ohio, in front of the TV and three weeks shy of my 8th birthday, I was elated to stay up late and watch the incredibly exciting Moon landing. Near the end of a decade that was as tumultuous as any in American history, this spectacular event of exploration promised to end the 1960s on a high note, with humankind's first visit to another world.

Nearing 11 P.M. on the East Coast, the crackly, low-resolution, black-and-white picture finally revealed Neil Armstrong climbing down Eagle's ladder and uttering those famous words, "That's one small step for [a] man, one giant leap for mankind." Six and a half hours had passed since the landing. In that instant, he, Buzz Aldrin, and Michael Collins had changed humanity forever. Years later, it was incredible to hear Buzz Aldrin describe the view he had approaching the lunar surface.

Neil A. Armstrong was the first human to stand on the lunar surface. NASA

How amazing to think that event took place 40 years ago! And humans last visited the Moon in 1972, 37 years ago. After making friends with the Moon, we abandoned it. More recently, the administration of George W. Bush, and now the Obama administration, have stirred a new Moon program that could place humans on our celestial neighbor once again by the year 2020.

This special "Return to the Moon" issue is packed with features that tell the story of recent missions and future plans for the Moon. Veteran space exploration journalist James Oberg brings you a magnificent overview of the new lunar program in "How we'll return to the Moon" (p. 24). To follow this, Associate Editor Daniel Pendick describes what may follow in "Next step Mars?" (p. 30).

Three recent lunar missions receive their due in two more stories. The first is "What Europe's Moon mission revealed," in which SMART-1 Project Scientist Bernard H. Foing recounts that recent mission's results (p. 44). Also, Senior Editor Michael E. Bakich describes Japan's KAGUYA (SELENE) and China's Chang'e-1 in his story "Asia's new assault on the Moon" (p. 50).

In addition to enjoying the issue, please make sure you enter our new sweepstakes. In partnership with Borders Bookstores and the Kennedy Space Center, we are presenting the "Train Like an Astronaut" Sweepstakes. The contest begins June 23 and concludes August 31. To enter, see page 16. The grand prizes are three trips to the Kennedy Space Center in Florida for 4 days and 3 nights to experience a unique tour that includes behind-the-scenes astronaut training, lunch with an astronaut, the Shuttle Launch Experience ride, and a private tour of the Kennedy Complex. Other prizes include a Meade 6-inch ETX-LS telescope and subscriptions and calendars from *Astronomy* magazine. Enter soon!

Yours truly,

David J. Eicher
Editor

Astronomy

Volume 37, Number 8

Editor David J. Eicher
Executive Editor Dick McNally
Art Director LuAnn Williams Belter

EDITORIAL STAFF
Senior Editors Michael E. Bakich, Richard Talcott
Associate Editors Liz Kruesi, Daniel Pendick
Online Editor Matt Quandt
Copy Editor Karri Ferron
Editorial Associate Valerie Penton

ART STAFF
Graphic Designer Chuck Braasch
Illustrator Roen Kelly
Production Coordinator Helene Tsigistras

CONTRIBUTING EDITORS
Bob Berman, Glenn F. Chaple, Jr., Phil Harrington, David Healy, Ray Jayawardhana, David H. Levy, Alister Ling, Steve Nadis, Stephen James O'Meara, Tom Polakis, Martin Ratcliffe, Mike D. Reynolds, John Shibley, Raymond Shubinski

EDITORIAL ADVISORY BOARD
Buzz Aldrin, Marcia Bartusiak, Timothy Ferris, Alex Filippenko, Adam Frank, John S. Gallagher III, William K. Hartmann, Paul Hodge, Anne L. Kinney, Edward Kolb, Stephen P. Maran, S. Alan Stern, James Trefil

CELEBRATING 75 YEARS
KALMBACH PUBLISHING CO. SINCE 1934

Kalmbach Publishing Co.
President Gerald B. Boettcher
Executive Vice-President Charles R. Croft
Vice President, Editorial, Publisher Kevin P. Keefe
Vice President, Advertising Scott Stollberg
Vice President, Marketing Daniel R. Lance
Corporate Art Director Maureen M. Schimmel
Managing Art Director Michael Soliday
Production Manager Annette Wall
Corporate Circulation Director Michael Barbee
Group Circulation Manager Paul Daniel
Single Copy Sales Director Jerry Burstein
Circulation Coordinator Sarah Zemplinski

ADVERTISING DEPARTMENT
(888) 558-1544
Advertising Director Scott Bong
Advertising Sales Manager Jeff Felbab
Advertising Sales Representatives
Craig Greuel, cgreuel@kalmbach.com
Ken Kozerski, kkozerski@kalmbach.com
Ad Services Representative
Sue Hollinger-Yustus, shollinger@kalmbach.com

RETAIL TRADE ORDERS AND INQUIRIES
Selling *Astronomy* magazine or products in your store:
Phone (800) 558-1544 ext. 818
Outside U.S. and Canada (262) 796-8776 ext. 818
Fax (262) 798-6592
E-mail tss@kalmbach.com
Website www.Retailers.Kalmbach.com

CUSTOMER SALES AND SERVICE
Phone (800) 533-6644; **Fax** (262) 796-1615
customerservice@kalmbach.com

SPECIAL E-MAIL ADDRESSES
Ad Sales adsales@astronomy.com
Ask Astro askastro@astronomy.com
Books books@astronomy.com
Letters letters@astronomy.com
Products products@astronomy.com
Reader gallery readergallery@astronomy.com

Editorial phone: (262) 796-8776; advertising: (888) 558-1544; customer service & sales: (800) 533-6644; outside the U.S. and Canada: (262) 796-8776, ext. 421, Monday through Friday, 8:30 A.M. to 5 P.M. CT, Fax: (262) 796-1615; E-mail: customerservice@kalmbach.com. Please include your name, mailing address, and telephone number with any correspondence.

Copyright © 2009 Kalmbach Publishing Co., all rights reserved. This publication may not be reproduced in any form without permission.

Printed in the U.S.A. Allow 6 to 8 weeks for new subscriptions and address changes. Subscription rate: single copy: $5.95; 1 year $42.95, 2 years (24 issues) $79.95, 3 years (36 issues) $114.95; Canadian price: 1 year $50.95, 2 years $95.95, 3 years $138.95 (Canadian price includes additional postage and GST, payable in U.S. funds.) International price: 1 year $58.95, 2 years $111.95, 3 years $162.95 (International price includes additional postage, payable in U.S. funds.) Expedited Delivery Service Surcharges: Domestic 1st Class $30 per year, Canadian air $30 per year, International air, $60 per year. BN 12271 3209 RT. Not responsible for unsolicited materials.

The Audit Bureau
KALMBACH PUBLISHING CO.
Please Recycle This Magazine

CELESTRON®

CGE Pro™ Series

CGE Pro 1400

A ROCK SOLID BASE OF OPERATION FOR EXPLORING THE UNIVERSE!

The CGE Pro Series is Celestron's "Top-of-the-Line" astronomical telescope which features a completely redesigned German Equatorial mount that offers numerous design advantages. This series thrives as a solid platform for long exposure photography with optional CCD cameras or photographic equipment; it is also a serious scientific research tool that comes with Celestron's premium StarBright XLT® coatings.

- **All-Star Polar Alignment**
  Choose any bright alignment star for a software assisted alignment of the mounts polar axis that will have you ready for imaging even if you can't see the North Star.
- **Finding A Star**
  With a standard hand control alignment, CGE Pro has the ability to center a star in your eyepiece or CCD chip to within 5 arc minutes. Using NexStar's advanced pointing features such as Calibration Stars, Sync and Precise GoTo, further improves the pointing accuracy to as low as 1 arc minute in the desired region of the sky.
- **Tracking A Star**
  With larger .75" pitch diameter worm, precision cut-steel gears and seven slot skewed armature motors the CGE Pro delivers typical tracking performance of +/-9 arc seconds, which can be further reduced with the mounts permanent periodic error correction (PPEC).
- **Meridian Tracking**
  Tracks up to 20 degrees past the Meridian for extended, uninterrupted imaging through the best part of the sky.
- **Increased Payload Capacity**
  Securely holds larger optical tubes with a maximum payload of 90lbs.

MODEL	ITEM#	PRICING
CGE PRO 925	11086	$5,999*
CGE PRO 1100	11087	$6,999*
CGE PRO 1400	11088	$8,999*
CGE PRO 1400 FASTAR	11089	$9,499*

*Price does not include shipping and tax.

For complete specifications and product information, visit: www.celestron.com

CELESTRON PREMIER SELECT DEALER

- Adorama – 800.223.2500 – www.adorama.com
- OPT Corp. – 800.483.6287 – www.optcorp.com
- High Point Scientific – 800-266-9590 – www.highpointscientific.com
- Optics Planet – 800.504.5897 – www.opticsplanet.com
- Scope City – 800.235.3344 – www.scopecity.com
- Astronomics – 800.422.7876 – www.astronomics.com
- Telescopes.com – 888.988.9876 – www.telescopes.com

Price is suggested retail in U.S. Dollars. Pricing subject to change without notice.

Astroconfidential

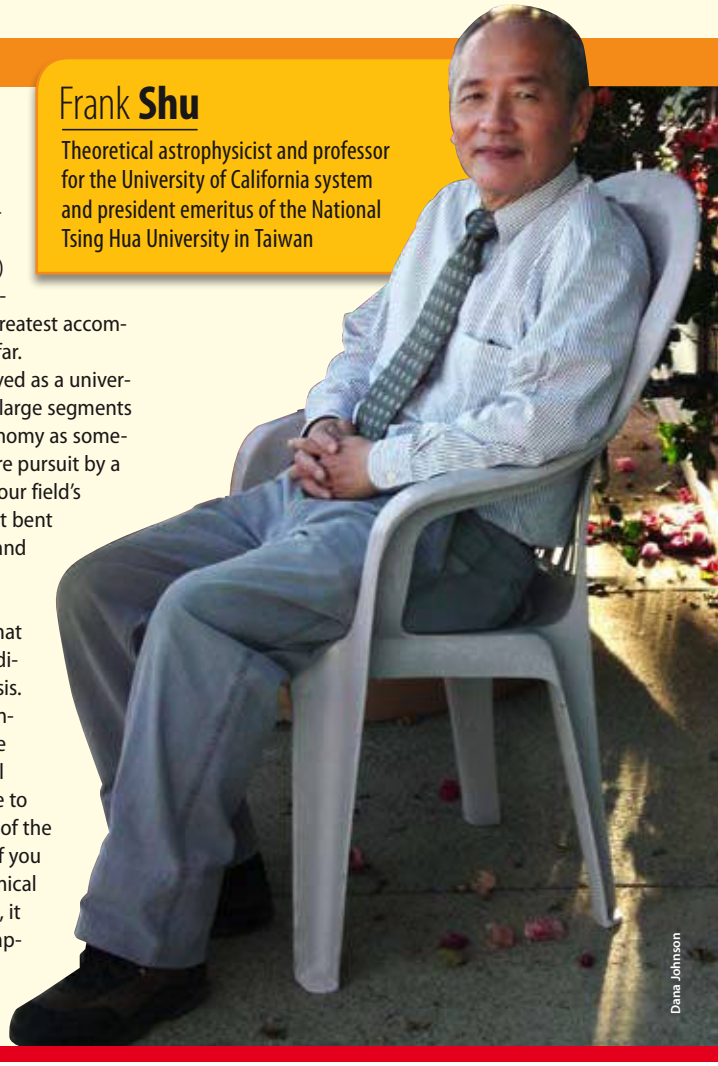
Go beyond the latest discovery, research, or theory and meet the professionals who make it all possible.

by Karri Ferron

GETTING TO KNOW

Frank **Shu**

Theoretical astrophysicist and professor for the University of California system and president emeritus of the National Tsing Hua University in Taiwan



Dana Johnson

Favorite topics to research: I've spent most of my career working on the spiral structure of galaxies (spiral density waves) and star formation. You never forget your first love, and spiral density waves are the reason I became a research scientist.

It was through spiral density waves that I became interested in star formation. Who could resist trying to find a connection between the beautiful, bright, young type O and B stars being born in galactic spiral arms and the wave pattern that underlay the phenomenon? However, the subject was not sufficiently developed in the early 1970s to allow much progress, so my attention wandered to other topics. But teaching graduate courses in gas dynamics and stellar structure and evolution at Berkeley revived my interest. Recently my co-workers and I have found what we believe to be an opening to revisit that old interest of mine: What is the relationship between massive-star formation and galactic spiral structure?

Greatest career moment so far: No research accomplishment has been as gratifying, perhaps, as the enthusiastic reception given to the 1982 publication of my first textbook, *The Physical Universe*. To this day, wherever I travel in the world, students or former students bring me tattered copies of this book and ask me to autograph it. (I knew I was getting old when the professors started asking me to do it, too.) So in terms of impact and influence, that book has been my greatest accomplishment in astronomy … so far.

Goals for your field: Having served as a university president, I am aware that large segments of pragmatic adults view astronomy as something of a luxurious and obscure pursuit by a few chosen acolytes. To polish our field's image, astronomers of the right bent must exploit their knowledge and skills to help solve some of the larger practical problems that face society today. Two areas that could benefit from this are medical imaging and the energy crisis.

In relation to the overwhelming issue of climate change, the energy crisis is at such a pivotal point that I feel I should devote to the problem the principal part of the rest of my scientific career. So if you don't see me much in astronomical circles in the next several years, it isn't because I've retired or disappeared; it's that I'm engaged doing this energy thing.

Astrofascinations *How did you get interested in cosmology?*

Dragan **Huterer**

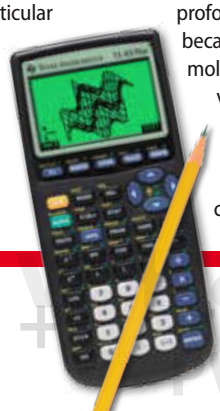
Assistant professor of physics at the University of Michigan

Courtesy Dragan Huterer

Before I got interested in cosmology, I got interested in physics. I had a high school physics professor in Sarajevo, former Yugoslavia, who sparked my interest with a combination of nonchalant lectures and funny jokes. He particularly liked to give bad grades to excellent students, of whom there were many — this was an elite school specializing in physics and math. Somehow I found this stimulating and fun, so I began doing physics problems in my spare time, going through various books of collected exercises.

I followed that up by attending physics competitions through the school, both at the regional and national level, which were popular in eastern European countries. At the time, I studied and competed in the classical physics — mechanics and thermodynamics, in particular — and knew nothing about astronomy, much less cosmology.

Then, at some point while I was in high school, I read an article in a Yugoslavian popular science magazine that talked about cosmic inflation and its proponent Alan Guth, professor at the Massachusetts Institute of Technology and "the cosmology guru," as the article called him. I confess I did not understand much of what the article was trying to convey, but it clearly had a profound effect on me, and I became fascinated with cosmology and the early universe. Several years later, I was an undergraduate at MIT. Guth taught my first cosmology course, and I was hooked.



To learn more about the people featured this month, visit www.Astronomy.com/toc.

Astroideas

Where is the study of star and planet formation going?

My colleagues and I are studying the disks of gas and dust that surround young stars to uncover clues to how stars and planets form. We also hope to learn about how our own solar system developed. While many astronomers focus on the dust grains in these disks, my colleagues and I study the gas in them. We try to determine what kinds of molecules are synthesized in disks. A chemically active disk may create molecules of biological interest. Such a process may have played a role in the origin of life on Earth.

We also intend to use these molecular tracers to search for evidence of any planets that may have formed in the disk. Planets are expected to create large radial gaps in the disks from which they form. We may be able to detect the signature of this change in the radial structure of the disk with high spectral resolution data. These kinds of measurements can test theories of planet formation.

Courtesy Joan Najita

Joan **Najita**

Astronomer at the National Optical Astronomy Observatory in Arizona

OUR TURN

Adam **Riess**

Professor at Johns Hopkins University and member of the science staff at the Space Telescope Science Institute, both in Baltimore

What were your thoughts when your team's research had produced evidence that the universe's expansion is accelerating?

For a long time, I was terrified that I had made a mistake in the data analysis — an extra negative sign, applying a correction twice, or a string of data out of order. Eventually, we came to accept that this was the right answer to the experiment, but the interpretation was too mind-boggling for me to be sure it was right. Within a few years, other experiments were coming to the same conclusion, and I remember thinking, "Wow, the expansion really is accelerating!"

What's next in understanding dark energy?

Although we know dark energy is accelerating the universe's rate of expansion, we don't yet understand its composition. We would like to gather a few clues that would distinguish it among the various possibilities. For example, is it static, or is it changing strength with time? Does it vary from place to place, or is it uniform?

Why is the study of cosmology important?

Cosmology allows us to engage in experiments beyond the scale and scope of those we can achieve on Earth. These experiments that probe the behavior of the universe at its extremes in size, energy, or time interval bring us closer to understanding fundamental laws of physics. Advancements on many fronts in science and technology frequently come from such a deeper understanding.

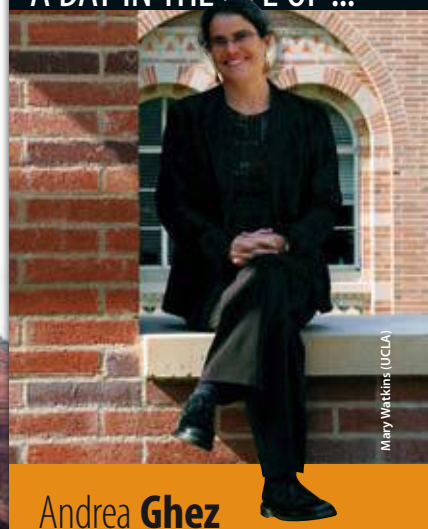
Cosmology also offers ways to pose and possibly answer questions about our origin and fate. Those who have pondered such questions understand the insatiable curiosity that drives one to study the universe.

In 2008 you received a MacArthur "Genius" Grant. What research will you explore with the grant?

I hope to contribute to our understanding of dark energy through a number of different projects and surveys. I think we have reached the end of the beginning in dark-energy studies, and the next decade is likely to be an interesting one for cosmology.

Will Kirk/Homewood Photographic Services
Background image: NASA, A. Riess, Hubble Heritage Team

A DAY IN THE LIFE OF ...



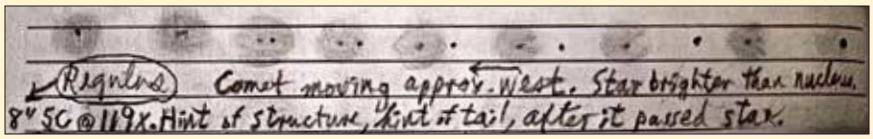
Mary Watkins (UCLA)

Andrea **Ghez**

Professor of physics and astronomy at the University of California, Los Angeles

- **8 A.M.** Scan through recently posted research papers on astrophysics and check e-mail.
- **9 A.M.** Begin my carefully guarded morning research time. Make progress on my research on the supermassive black hole at the center of the Milky Way and its environs. Put final touches on a manuscript so that I can send it out to my collaborators for their comments.
- **1 P.M.** Meet with my research team of graduate and postdoctoral students to discuss plans for our upcoming observing run at the Keck Telescope. We'll measure the kinematics of stars at the center of the Milky Way to try to figure out how the young stars near the supermassive black hole formed. It's a remarkably inhospitable environment for star formation, and one might think that it shouldn't happen … and yet it did because we see the products!
- **3 P.M.** Lead a committee meeting to discuss candidates who have just interviewed for our open assistant professor position and hope that we can reach a consensus.
- **4 P.M.** Attend the Department Colloquium, a weekly talk given by an astronomer from another university. It's a great opportunity to learn what is going on in the broader community and for that community to come in and find out what is happening at UCLA.
- **5:30 P.M.** Pick up kids from daycare.
- **9 P.M.** Prepare for tomorrow's lecture on the structure of main sequence stars for an introductory astronomy course.

The power of your eyes



John Mood observed the nucleus of Comet C/2007 N3 (Lulin) occult a star in February and sketched the event the following morning. His sketches are in chronological order from left to right. Courtesy Stephanie Mood

The camera can see things the human eye cannot. Each issue of *Astronomy* provides dramatic evidence of that. But many forget that the human eye can see things the camera cannot. On February 27, I had a thrilling reminder of that.

From Ocotillo, California, in the Anza-Borrego Desert, I observed the nucleus of Comet C/2007 N3 (Lulin) occult a star through my 8-inch f/10 Schmidt-Cassegrain scope at 119x. At first, I could not tell what was happening. Then the comet's nucleus began to elongate. I saw two dots of light, and I realized one was a star. I continued observing for about an hour (from 7 to 8 P.M. PST) and saw the comet's tail leave the star behind. The next morning I made eight sketches of this memorable sight. **— John Mood,** San Diego

Make your own shadow bands

I enjoyed Stephen James O'Meara's article about shadow bands, "Serpents of the air," in March. I live 60 miles southwest of Seattle in a wooded setting where I do not have a flat, sharp plane of horizon to enjoy this phenomenon. However, I do have the benefit of a much smaller version with a darkened room, a wood stove (convection heaters also work), and a single source of bright light. The heat radiating from the surface of the stove roils the air currents, which produces an effect similar to shadow bands on the wall of my living room. It works best with natural convection and disappears with a fan. The fan homogenizes the air currents.

At a reciprocal angle, one can sometimes see the air currents themselves, which is not unlike looking at details in Jupiter's cloud bands. **— Frederick J. Nachbar,** Shelton, Washington

The curious Sun

John Anderson's article "Is there something we don't know about gravity?" in March sparked a couple of questions about the astronomical unit (AU). On page 24 in the section headed "Astronomical Unit inflation," the first paragraph says that the AU "seems to be increasing, thus effectively increasing the Sun's gravitational attraction." To me, this statement sounds backward.

Also, the section ends with "However, the AU should not change at all!" Shouldn't the AU be increasing for the simple reason that the Sun continuously loses mass as particles in the solar wind stream into interstellar space and because the Sun loses mass equivalent to the amount of energy it radiates? Are these effects significant to the current measurement precision? **— Curtis McCollister,** Fishers, Indiana

The AU is defined as the radius of a circular orbit in which a body of negligible mass would revolve around the Sun in about 365.2569 days. The Sun's mass and the AU are directly associated by an astronomical constant k. *Carl Friedrich Gauss (1777–1855) introduced* k *to standardize the length scale in the solar system to the average Sun-Earth distance. If the Sun's mass increases, so does the AU.*

The Sun does indeed lose mass by radiation and to a much lesser extent by the solar wind, but this amounts to the AU decreasing by about ⅓ centimeter per year. Something else must cause the measured increase of at least 2.8 inches/yr (7 cm/yr) as discussed in my article. A gain in solar mass per year will result in an equivalent decrease in a planet's orbital radius per year, and an increase in the AU (Sun's mass and the AU are directly related). The solar system shrinks with increasing solar mass and expands with decreasing solar mass.
— John Anderson, Consultant for Juno and Rosetta space missions

Reflecting plastic bag?

In "Is there something we don't know about gravity?" (March), John Anderson mentioned that there is a 0.2-inch discrepancy with the orbit of our Moon. Could the plastic bag lying on the ground about 4 feet from the laser reflector have anything to do with this problem? No doubt a plastic bag makes an inefficient mirror, but wouldn't even the tiniest reflections throw off the calculations?
— Richard Jansen, Marcellus, New York

No, it is hard enough to get a laser signal back from the reflectors. Plastic bags won't interfere with readings. Besides, astronomers use four reflector packages at different locations. The Apollo 11, 14, and 15 astronauts left three on the lunar surface, and the Lunokhod 2 Soviet rover left the fourth.
— John Anderson, Consultant for Juno and Rosetta space missions

Correction

In May's "How the telescope remade the universe," the explanation on page 34 about chromatic aberration and how different colors of light bend is wrong. The sentence concerning red and blue light should say, "Blue bends the most and red the least." **— *Astronomy* Editors**

We welcome your comments. Send letters to Astronomy *Letters, P. O. Box 1612, Waukesha, WI 53187; e-mail to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.*

Webtalk

The ultimate deep-sky observing guide

Astronomy magazine's popular deep-sky observing series **"Celestial Portraits"** is now available in digital format. Each package, $8.95, contains four articles that feature:

- **Lists of each constellation's deep-sky gems**
- **Easy-to-read star charts**
- **Constellation mythology**

The collection includes 11 digital packages, all 88 constellations, and tips to observe more than 500 deep-sky objects! Browse the collection at www.Astronomy.com/Portraits.

FREE WEEKLY E-MAIL NEWSLETTER! Receive astronomy news, sky-event information, observing tips, and more. **SIGN UP TODAY!**

MULTIMEDIA

Featured Video

In "How to buy your first telescope," *Astronomy* magazine Senior Editor Michael E. Bakich shares 10 tips to help you pick the telescope that's right for you.

Podcasts

Senior Editor Michael Bakich's weekly series helps you find three objects or sky events you can see.

COMMUNITY

Editors' Blogs

Read insights from behind the scenes of the science, hobby, and magazine.

News

Check the daily astronomy headlines.

Reader Forums

24/7 astronomy! Share and learn observing tips, get advice on an equipment purchase, or discuss the latest cosmological conundrum with fellow astronomy enthusiasts.

OBSERVING TOOLS

Jupiter

The Sky this Month

Read the complete version of August's "The Sky this Month" online.

Star Atlas

Use this interactive sky chart to zoom in and out on 24 sky maps.

StarDome and StarDome Plus

Map your night sky and find out what objects are visible and where from your own backyard.

denotes subscriber-only content

Jupiter: NASA/JPL/SSI

REGISTER TODAY! Subscribers get unlimited access to everything Astronomy.com has to offer, including customer-service support. It's easy! Go to www.Astronomy.com/register.

David H. Levy
Comet Hunter™
Special Edition Telescope

$1199

Co-designed and field tested by comet discoverer David Levy, the Comet Hunter produces stunning wide-field views through your favorite eyepiece or CCD!

- 152mm Dia. f/4.8 Mak-Newtonian
- EMD Coatings
- 10:1 Two-Speed Focuser
- Carbon Fiber Tube
- Cradle Rings and Mounting Plate
- Deluxe Case
- 70° Series™ 30mm 2.0" O.D. Eyepiece
- 8x50 Erect Image Illuminated Finder
- Five Year Limited Warranty*

*Requires Product Registration

EXPLORE SCIENTIFIC™
888.599.7597
explorescientific.com

Strange Universe

by Bob Berman

Edges of the universe

Make sense of ultra-distant galaxies in an expanding universe.

Last year, researchers found one of the farthest-ever galaxies. This smudge on a Hubble photo is said to sit at a distance of 13 billion light-years (abbreviated 13 Gly). It was born soon after the Big Bang and has been given the catchy name A1689-zD1.

But viewing galaxies whose light traveled a long time through an expanding universe introduces several bizarre twists in understanding. Let's finally get this straight, once and for all.

Nothing is particularly screwy in our own close-up neighborhood of space, at least outside Washington. The galaxy M87 in the Virgo cluster lies some 50 million light-years away. So its light took that long to get here. That's short compared with its age of at least 8 billion years; its image is therefore a current, accurate snapshot. Also, the distance from here to M87 grows by 800 miles (1,300 kilometers) every second. This redshifts (stretches) its light, which makes the galaxy slightly dimmer. The effect is barely noticeable because M87's recession is less than 1 percent of light-speed.

Even if we jump 20 times farther and observe any of the 60 million galaxies that float within 1 billion light-years of Coney Island, we see them essentially where they really are and how they look today.

But now the fun begins. Because the speed of the expanding universe increases with distance, weird stuff happens to truly faraway objects. Take A1689-zD1. We can say it's old because we see the galaxy as it was when its light started traveling to us 13 billion years ago. The galaxy's image is ancient. We can also say it's young because we're viewing a picture of a newborn object.

But is this galaxy really 13 Gly away, as the news articles claim? Cosmologists use cool calculators to answer this sort of thing. When the image we're seeing left A1689-zD1, we were much closer together. It was then only 3.35 Gly from us. So the image should logically display the size of a galaxy at that nearer distance, when its light left, rather than the distance the light had to cover in order to get here. The image's dimensions don't change just because it took a long time to reach us.

Amazingly, that galaxy does look larger than we'd expect for something so far away. It measures 1/67 the angular size of nearby Virgo galaxies of the same type. If it were 13 Gly away, it would appear 1/260 the size of Virgo galaxies. Holy cow! It's like a funhouse mirror. The galaxy *appears* much closer than it is!

Because the speed of the expanding universe increases with distance, weird stuff happens to truly faraway objects.

In size, that is. But it's far dimmer than we'd expect a 13 Gly object to be. Space has been stretching all the time its image traveled, dramatically redshifting and weakening the light. It now exhibits the ultra-faintness of a galaxy at the impossible distance of 263 Gly.

Let's put all this together. It's the oldest galaxy image we've ever seen, which also makes it the youngest. It looks way too big for its distance, but also way too faint. Could things get any weirder?

You bet. Science articles say it's 13 Gly from here because distance is often expressed that way. But that's merely how long its light took to reach us. During all that time, A1689-zD1 has been madly receding. This galaxy is now actually 30 Gly away. To get the true figures for these kinds of questions, use the calculator cosmologist Ned Wright of UCLA posts. Punch in a light-distance, and it'll give you the rest: http://www.astro.ucla.edu/~wright/DlttCalc.html.

Now consider cosmic boundaries. The first stars or protogalaxies may have formed as early as 100 million years after the Big Bang; it's still debated. If so, they'll display angular sizes as if they're just 1.2 Gly away. But their brightnesses would indicate an inconceivable distance of 1.2 *trillion* light-years — utterly undetectable. Their actual distance today would be 38 Gly. These parameters roughly mark the edges of the observable universe.

But objects do not end there. Most galaxies were never positioned for their light to be able to arrive here at all. Astronomers such as Wright believe at least 98.4 percent of the universe lies "over the horizon" in a zone that can never be observed. This can be a frustrating limitation. For example, something massive is disrupting the universe's smooth expansion in our region of space. Some sort of "great attractor" lies in the direction of Centaurus. Many astronomers think it's located outside our observable reality. It tugs on our visible universe from a place beyond.

That "place beyond" constitutes nearly all of the cosmos. And where does *that* end? No one's sure, but it's likely the universe is, was, and always will be infinite in extent. If this is true, everything we can ever see represents *0 percent* of the total galactic inventory.

Find more of my strange universe at **skymanbob.com.**

Observing Basics

by Glenn Chaple

Double the observing fun

Split some binary stars or measure an eclipsing binary's change in brightness.

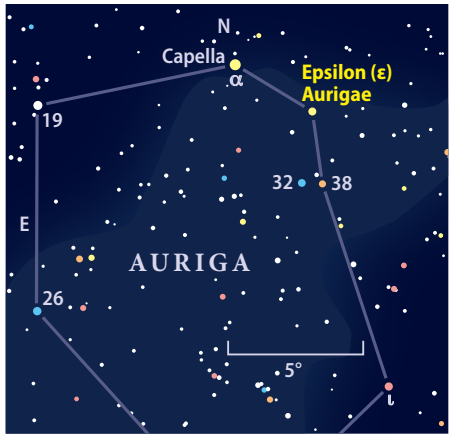
In an article published in the October 1977 issue of *Deep Sky Monthly*, I wrote that Jean Baptiste Riccioli discovered the first double star, Mizar (Zeta [ζ] Ursae Majoris), in 1646. I based my information on what commonly appeared in astronomy texts. How odd, I thought, that nearly 4 decades should pass from the time of the telescope's invention to the discovery of the first double star. After all, the night sky teems with stellar partnerships.

My skepticism proved well-founded. Last winter, I came across an article (www.leosondra.cz/en/mizar) detailing recent studies that point to Galileo's one-time student Benedetto Castelli as Mizar's true discoverer. Castelli detected the star's duplicity in 1617 and quickly notified Galileo. Galileo observed and measured what his student had described as "one of the most beautiful things in the sky." Many organizations now list Castelli as the discoverer of this double star.

And beautiful it is! Easy to locate (it's the middle star in the handle of the Big Dipper), Mizar is a dazzling telescopic sight. Two sparkling pure-white diamonds of magnitudes 2.3 and 3.9 lie 14" apart — a gap that you can readily breach with a small telescope and a magnifying power of just 30x. Visible in the same field is Mizar's naked-eye companion, the 4th-magnitude Alcor.

In this era of gigantic Dobsonian-mounted reflectors, remote galaxies have taken center stage, pushing double stars to understudy status. To me and a small but loyal group of double-star aficionados, Mizar and its kindred pairs pack a visual punch that the "faint fuzzies" can never replicate.

On evenings when a Full Moon or urban lights conceal galaxies, double stars continue to shine unabated. I may have erred in writing about the circumstances surrounding the discovery of the first double star, but I was right on target when I declared that "double stars are twice the fun!"



Astronomy: Roen Kelly

Use this finder chart to record changes in Epsilon (ε) Aurigae's brightness. The magnitudes (decimal points have been removed) of the comparison stars will help with your estimates.

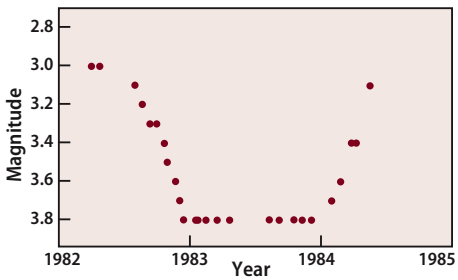
Many double stars are too close to resolve through backyard scopes. Some are gravitationally bound pairs whose edge-on orbits cause mutual eclipses. These eclipses produce a periodic dimming of the system as a whole.

One of the most unusual eclipsing binaries is Epsilon (ε) Aurigae. Unlike the majority of eclipsing binaries whose fade-aways occur every few days and last several hours, Epsilon Aurigae has a period that lasts 27.1 years and an eclipse duration of nearly 2 years! Astronomers believe Epsilon Aurigae's eclipses are caused not by the companion star itself but by an extensive, dusty accretion disk that surrounds the companion star.

A key project for this International Year of Astronomy calls for amateur astronomers to monitor the next Epsilon Aurigae eclipse, predicted to get underway in August. Epsilon Aurigae is currently in the predawn sky, but it will become an evening object in the months ahead. The eclipse will continue throughout 2010 and end in May 2011. You can document the drop in magnitude, from 3.0 to 3.8, with biweekly to monthly naked-eye observations. If you make these brightness estimates, you'll have a dramatic record of one of the night sky's most unusual events. Don't miss it — the next eclipse won't occur until 2036! Log on to the American Association of Variable Star Observers' web site at http://www.aavso.org/aavso/iya.shtml for more information.

For those wishing to know more about double stars, I recommend Joe DalSanto's book, *A Field Guide to Double Star Observing*. His nontechnical approach includes background information about the nature of double stars, a brief history of their discovery, and observational hints. He concludes with a list of more than 400 bright and easily resolved double, triple, and multiple stars visible from northerly latitudes. You can obtain information about ordering a copy, which costs $20, by e-mailing Joe at jdalsanto@waubonsee.edu.

Questions, comments, or suggestions? E-mail me at gchaple@hotmail.com. Next month: We cruise the summer Milky Way. Clear skies!



Epsilon (ε) Aurigae's brightness changed during a 2-year eclipse period in the 1980s. Each point on this light curve is an amateur astonomer's visual estimate of the change. *Astronomy*: Roen Kelly, after the American Association of Variable Star Observers (AAVSO)

CELEBRATING THE 40TH ANNIVERSARY OF MAN'S FIRST STEPS ON THE MOON

train like an astronaut sweepstakes

enter and you could

win a grand prize trip for four to Kennedy Space Center Visitor Complex

where you'll perform a mock space shuttle mission, meet an astronaut, ride simulators & more!

other prizes include:

- Meade ETX-LS telescope
- *Astronomy* magazine subscriptions
- *Astronomy* calendars

See official rules.

to enter, visit Borders.com/moon

BORDERS®

Kennedy Space Center® VISITOR COMPLEX

Astronomy magazine

SAVE $5 on admission

Kennedy Space Center® VISITOR COMPLEX

Visit the gateway to space exploration at Kennedy Space Center Visitor Complex as we celebrate the 40th anniversary of man's first steps on the moon!

Redeem this coupon at the ticket window or go to KennedySpaceCenter.com and save $5.00 on admission.

Promo code: MOONWALK

232794

This coupon is not valid with any other discount or special ticketed event. No cash value. Valid up to six admissions purchased on one transaction. Expires on 12/31/09.

visit Borders for space-related books and more!

OFFICIAL RULES

1. NO PURCHASE NECESSARY. Enter to win. The Train Like an Astronaut Sweepstakes starts 12:01 AM Eastern Time ("ET") on June 23, 2009, and ends at 11:59 PM Eastern Time ("ET") on July 27, 2009 ("Promotion Period"). Winners will be selected on or about September 27, 2009, with winner verification to follow. Winners must complete travel to Kennedy Space Center Visitor Complex by April 30, 2010.

2. ELIGIBILITY: Sweepstakes is open to legal residents of the United States and Canada (except Quebec) only, ages 8 as of March 2009. Void in Puerto Rico, U.S. territories and possessions, and where prohibited or restricted by law. Employees and agents of participating stores, Borders Inc., Kalmbach Publishing Company, and DNC Parks & Resorts at KSC, Inc. and their respective parent companies, affiliates, subsidiaries (collectively, the "Promotion Parties") are ineligible to participate. Each participant under 18 years of age must obtain signature of his/her parent or legal guardian to enter and for the collection of his/her name, address, and age.

3. HOW TO ENTER: During the promotion period, visit Borders.com or Astronomy.com, complete an entry form and submit it during the entry period or mail in a postcard with your name, address, city, state or province, and zip or postal code to: The Train Like an Astronaut Sweepstakes, P.O. Box 378, Waukesha, WI 53187-1199. The Online Entry Form must be filled out completely to be eligible. Incomplete or defaced entry forms are void. The official ending date for The Train Like an Astronaut Sweepstakes will be July 27th, 2009, and all entries must be transmitted or postmarked no later than that date. Limit one entry per day per household. A purchase will not increase your chance of winning.

4. PRIZES AND ODDS:
Grand Prize Winners – Three Families of Four
A 4-Day/3-Night trip for winner and three guests to Kennedy Space Center Visitor Complex in Florida, which will include round trip economy air travel for four (4) from the airport nearest winner's home to Orlando, Florida; three (3) nights accommodations (one quad occupancy room); and car rental for four (4) days. In addition, participation in the Family Astronaut Training Experience; lunch with an astronaut; riding the Shuttle Launch Experience; a guided tour of Kennedy Space Center; and a Commander's Club Annual Pass. Approximate Retail Value ("ARV"): $2,825 per family of four. No substitutions, no cash redemptions, no transfer of prize. Odds of winning depend upon the number of eligible entries received. Winners will be notified. If unable to contact prizewinner within fourteen (14) working days, an alternate winner will be randomly selected.

First Prize – Meade 6" ETX-LS Telescope (Retail value: $1,299). Second Prize – Ten 1-Year Subscriptions to Astronomy magazine ($42.95 Value Per). Third Prize – 10 Astronomy Calendars (Retail Value: $12.95).

5. PRIZE CONDITIONS: One winner per household. Each potential prizewinner will be required to execute an Affidavit of Eligibility ("Affidavit/Release"), except where prohibited. Potential prizewinner parent/legal guardian will complete Affidavit/Release on behalf of the prizewinner within fourteen (14) days of notification. If such documents are not returned within that time, or if an entrant is found to be ineligible, or if he/she does not comply with the Official Rules or if prizes or prize notifications are returned as undeliverable, then such potential winner will be disqualified and an alternate winner will be selected. Noncompliance with this condition will result in forfeiture of prize and an alternate winner being selected.

6. GENERAL RULES: All income taxes resulting from acceptance of a prize are the responsibility of winner. Potential winners will be notified by mail and may be required to sign (or a parent or legal guardian must sign if potential winner is deemed an eligible minor in his/her state of residence) any required Affidavit and Release within seven (7) days of attempted delivery or prize will be forfeited. If any prize/prize notification is returned as undeliverable, or in the event of non-compliance with any other requirements, the prize will be forfeited in its entirety. By participating, entrant accepts and agrees to these Official Rules and the decisions of Judges, which shall be final in all matters. By accepting prize, winner agrees to hold Promotion Parties, DNC Parks & Resorts at KSC, Inc., their respective parents, affiliates, directors, officers, employees and assigns harmless against any and all claims and liability arising out of use or redemption of prize. Acceptance also constitutes permission to the Promotion Parties to use winner's name, likeness and biographical information for marketing purposes without further compensation or right of approval, unless prohibited by law. Promotion Parties are not responsible for lost or late mail, or for technical, hardware or software malfunctions, lost or unavailable network connections, or failed, incorrect, inaccurate, incomplete, garbled or delayed electronic communications whether caused by the sender or by any of the equipment or programming associated with or utilized in this promotion, or by any human error which may occur in the programming of this promotion. If due to a computer programming or other error, more prizes are claimed than intended to be awarded according to Rule 4, such prize(s) will be awarded in a random drawing from among all prize claims received. In no event will Sponsor be liable for more than the stated number of prizes in Rule 4. If, in the Judges' opinion, there is any suspected evidence of tampering with any portion of the promotion, or if technical difficulties compromise the integrity of the promotion, the Judges reserve the right to modify or terminate the promotion in a manner deemed reasonable by the Judges, at the Judges' sole discretion. In the event a dispute arises as to the identity of a potentially winning online entrant, entries made by internet will be declared made by the name on the online registration form. All federal and state laws apply.

7. WAIVER: By entering this promotion, participants (and if a minor, their parents/legal guardians) waive all rights to claim punitive, incidental and consequential damages, attorneys' fees or any damages other than actual out-of-pocket costs incurred to enter.

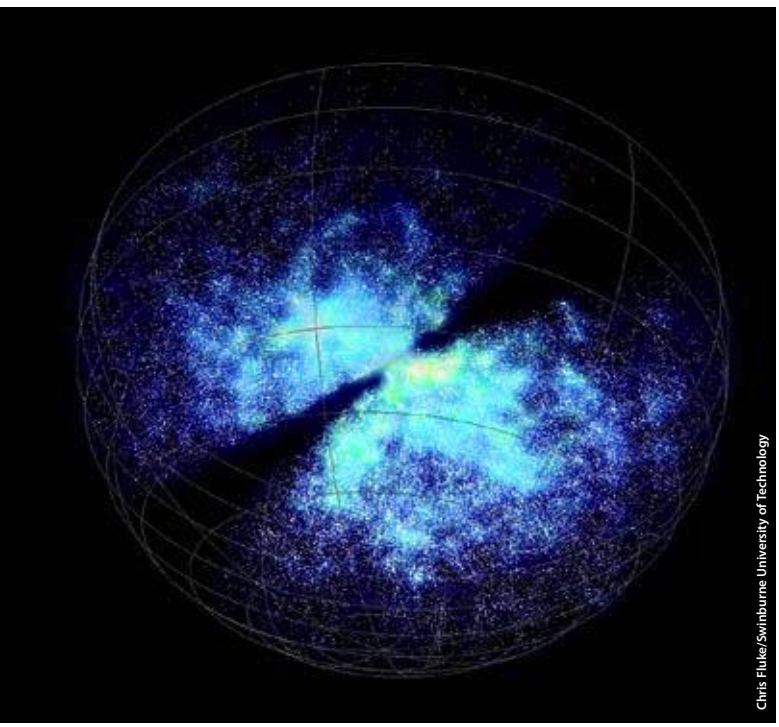
8. WINNERS LIST/RULES: For a list of winners, send a stamped, self-addressed envelope to: Train Like an Astronaut Sweepstakes Winners List, P.O. Box 1612, Waukesha, WI 53187-1612. Residents of FL, VT, and WA may omit stamp. Request must be received by September 1, 2009. You may also visit Borders.com to view the Official Rules.

9. SPONSOR: Kalmbach Publishing Co.

Stamps of approval On April 2, Canada Post issued two stamps to celebrate 2009 as the International Year of Astronomy. Each pairs a Canadian observatory with a celestial image.

For the latest news on space discoveries, spacecraft missions, and sky events, visit **Astronomy.com/news**

Astronews



Seeing structure. Astronomers gathered data on more than 110,000 galaxies to create this 3-D map of the nearby universe. This data covered more than twice the amount of sky that other surveys have studied.

New survey reveals cosmic structure

Astronomers have observed enormous voids and strings of galaxies in the most detailed map ever created of the nearby universe. The Six Degree Field Galaxy Survey (6dFGS) recorded the positions and distances of more than 110,000 galaxies within about 2 billion light-years of Earth. It covered some 80 percent of the southern sky, which is more than any similar survey. The international team, led by Heath Jones of the Anglo-Australian Observatory, submitted its findings to the *Monthly Notices of the Royal Astronomical Society* April 1.

Galaxies undergo two different types of movements: they gravitationally tug on each other, and they also ride along with the universe's expansion. Astronomers will use 6dFGS data to tease out these two movements for about 10 percent of the galaxies the survey recorded.

The team of researchers used the 1.2-meter UK Schmidt Telescope operated by the Anglo-Australian Observatory at Siding Spring Observatory, Australia. The telescope has a wide field of view, 5.7° compared to the 0.5° Full Moon, which enabled the survey to cover 80 percent of the southern sky in 6 years. — **LIZ KRUESI**

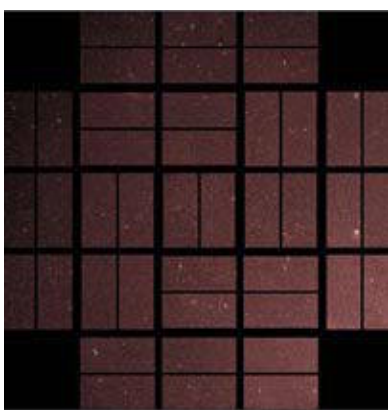
19 Plasma cloud tracked in 3-D

20 These galaxies don't fit the mold

20 Dawn of a new day

21 Black hole jets observed in new light

22 A near-Earth-sized exoplanet discovered



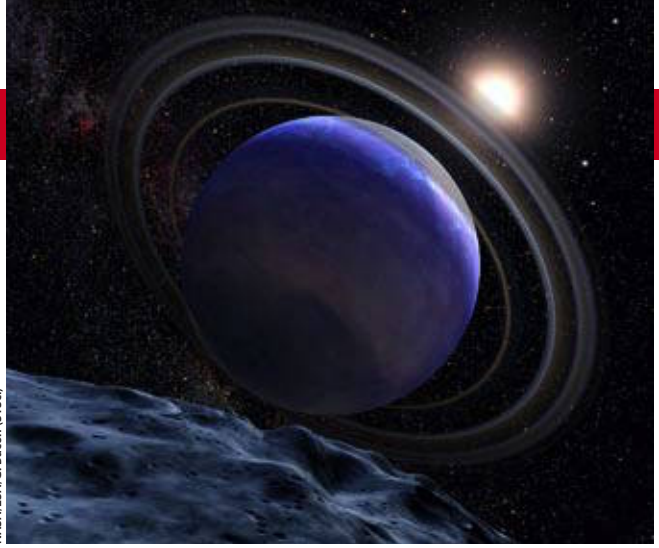
First light. NASA's Kepler took its first images of the area in which it will search for planets. Kepler will stare at the same 100-square-degree field of view for 3.5 years. NASA/AMES/JPL-Caltech

Kepler opens its eyes

NASA's Kepler satellite snapped its first images April 8 of the portion of the sky where it will search for extrasolar planets, including earthlike worlds. Kepler will stare at a 100-square-degree field of view — roughly two side-by-side dips of the Big Dipper — in the Cygnus-Lyra region for the next 3.5 years. During that time, it will look for periodic dips in starlight produced by planets passing in front of their parent stars. Kepler's 95-megapixel camera can detect brightness changes of 20 parts per million.

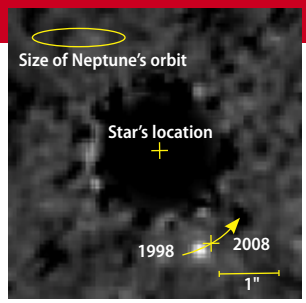
Astronomers expect that the mission will find hundreds of planets. Kepler's field of view holds some 4.5 million stars, and astronomers have picked about 100,000 of those as good candidates to harbor planets.

"Everything about Kepler has been optimized to find Earth-size planets," says James Fanson, the Kepler project manager at JPL. Astronomers have found some 350 extrasolar planets, but most are Jupiter-sized worlds that orbit near their suns. Kepler is the first mission that can detect earthlike planets orbiting near a star's habitable zone — an area around the star where liquid water can exist. — **L. K.**



NASA/ESA/G. Bacon (STScI)

Planet found. Astronomers announced the discovery of giant planet HR 8799 b (shown here in an artist's rendition) in 2008. However, after an archival search through Hubble Space Telescope images, researchers found that the telescope had imaged this planet in 1998.



Hide-and-seek. In 1998, the Hubble Space Telescope took this coronagraphic image using its Near Infrared Camera and Multi-Object Spectrometer (NICMOS). The planet HR 8799 b is the bright spot in the bottom right. NASA/ESA/D. Lafrenière (University of Toronto, Canada)

Astronomers find first directly imaged exoplanet in old data

Astronomers used a new image-processing technique to remove starlight from old Hubble Space Telescope images and discovered an extrasolar planet. In a photo from 1998, David Lafrenière of the University of Toronto and colleagues found a planet orbiting the dusty young star HR 8799 some 130 light-years away. The Space Telescope Science Institute in Baltimore, which operates Hubble, announced the finding April 1.

This isn't the first time HR 8799 and its planetary system have made headlines. In November 2008, a team of astronomers announced the first direct image of a multiplanet system around this same star. However, with this new information, it appears Hubble imaged the first exoplanet some 10 years prior. The new technique that Lafrenière and colleagues used allows them to "see planets that are one-tenth the brightness of what could be detected before with Hubble," Lafrenière says.

During the past 10 years, Hubble has imaged more than 200 stars using a device called a "coronagraphic spot" that blocks a star's obscuring glare. Astronomers plan to use the team's new technique to scrutinize the 200 archived star images to try to spot other previously undetected exoplanets. — **L. K.**

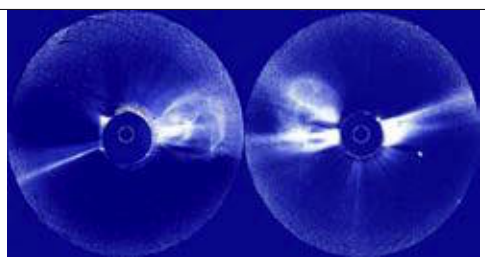
Plasma cloud tracked in 3-D

On April 14, scientists announced the first 3-D measurements of the shape, speed, and trajectory of a huge solar plasma cloud known as a coronal mass ejection (CME). NASA's Solar Terrestrial Relations Observatory (STEREO) made the observations.

STEREO's twin spacecraft view the Sun from different vantage points — one leads Earth as it orbits the Sun, and the other trails. These unique 3-D images show STEREO has the ability to track a CME from the Sun to Earth. "Using STEREO observations, we can extract a CME's properties and are able to determine when it will reach Earth, at what speed, and with how much energy it will impact Earth's magnetosphere," says Angelos Vourlidas, project scientist for STEREO's imaging suite.

Tracking CMEs is vital to "space weather" forecasting. Powerful CMEs can disturb electromagnetic fields on Earth, inducing extreme currents in the power grid and causing widespread blackouts. CMEs also can disrupt cell phone service and communications between the ground and satellites.

CMEs don't lack a positive side, however. They can ignite beautiful auroral displays that extend beyond the traditional polar locations. STEREO should serve as an early warning system for observers, as well. — **RICHARD TALCOTT**



Stereo view. The twin STEREO spacecraft caught these differing views of a mid-December coronal mass ejection (CME). By imaging the Sun from different vantage points, the two spacecraft can track a CME from its eruption until it reaches Earth. NASA

QUICK TAKES

BIG BURST
The European Integral satellite observed a 500-second burst of gamma radiation from a dying star — one of the brightest such gamma-ray bursts ever seen, researchers announced April 3.

CLUSTER CRACKUP
Astronomers released a composite image April 16 of four enormous galaxy clusters colliding.

SUNBATHING DUST
Direct sunlight enhances the static stickiness of lunar dust, according to research announced April 17. The finding may lead to better dust-busting strategies in future lunar exploration.

COOLEST DWARF EVER
The coolest brown dwarf ever found is 572 °F (300 °C) and orbits a star 40 light-years away, scientists announced April 19. Brown dwarfs are larger than Jupiter, but smaller than stars.

POWER TO GOCE
ESA turned on its Earth-orbiting gravity probe GOCE's electric ion propulsion thrusters by April 2, and they're working properly.

COMPLICATED FINDING
On April 22, an international team reported finding two of the most complex molecules ever detected in interstellar space: ethyl formate and n-propyl cyanide.

HEAVY LOSSES
Giant gaseous exoplanets orbiting close to their stars may lose a quarter of their mass during their lifetimes, researchers reported April 22 at a meeting of the Royal Astronomical Society.

OLD WATER
Astronomers found the most distant signs of water to date, according to findings announced April 22. The water was emitted from a galaxy when the universe was about 2.5 billion years old.

SLEEPING ON THE JOB
The Spirit rover on Mars missed a preprogrammed morning wake-up call April 9 to reactivate. After snoozing for 27 hours, the robot finally revived.

MOON TREES
NASA celebrated Earth Day and the 40th anniversary of the first Apollo Moon landing with a tree planting ceremony April 22 at the National Arboretum in Washington. The trees germinated from seeds taken to the Moon with Apollo 14 in 1971.

NASA/ESA/The Hubble Heritage (STScI/AURA)-ESA/Hubble Collaboration

Not quite right. **Most bright, giant galaxies such as NGC 1132 formed shortly after the Big Bang. But astronomers found 15 massive galaxies that formed in the past 3 to 4 billion years.**

These galaxies don't fit the mold

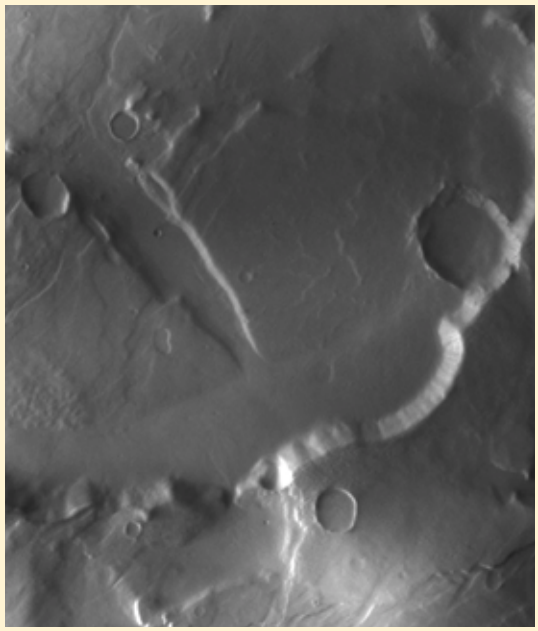
A new astronomical survey has uncovered 15 massive galaxies that don't follow the known rules of galaxy formation. Luminous, massive galaxies such as the Milky Way began forming not long after the Big Bang, which makes them about 10 to 12 billion years old today. However, these 15 bright, massive galaxies are just 3 to 4 billion years old. A team of astronomers, led by John Salzer of Indiana University, published a study of the galaxies April 10 in *The Astrophysical Journal Letters*.

As galaxies evolve, massive stars burn fuel and convert light elements (such as hydrogen and helium) into heavier elements (such as carbon and iron) called "metals." When these stars end their lives, they explode as supernovae, dispersing metals through space. Therefore, older galaxies should have a higher abundance of metals.

Salzer and colleagues found these 15 galaxies out of 2,400 in the Kitt Peak National Observatory International Spectroscopic Survey. The astronomers studied each galaxy's rainbow of wavelengths — called a spectrum. The 15 galaxies' spectra showed far fewer metals than the other galaxies.

The astronomers also suggest other reasons as to why these 15 bright galaxies have such low metal abundance. One possibility is that their brightnesses could have resulted from recent mergers between smaller galaxies. In mergers, star formation would increase brightnesses. Another possibility is that a large amount of pristine gas (lacking metals) may dilute the metal amount. **— L. K.**

Dawn of a new day



NASA/JPL/MPS/DLR/IDA/The Dawn Flight Team

Foggy bottom. **Dawn's framing camera captured this view of the northwestern edge of Mars' Tempe Terra region during the spacecraft's February 17 flyby. Traces of fog cling to the terrain near the image's bottom.**

Imagine a dusty disk the size of our solar system where rocks continually smash together. In some of the impacts, the objects destroy each other and create more dust. In others, the colliding rocks stick together and form a bigger object. Eventually, some of these accreting bodies grow tens, hundreds, and even thousands of miles across.

Planetary scientists think this is what the solar system's early days looked like. Yet the evidence has mostly disappeared. The surfaces of the planets and large moons have been reworked during the 4.6 billion years since the solar system's birth. And primitive meteorites offer only tantalizing glimpses at this early epoch.

All this will soon change. NASA's Dawn spacecraft, launched September 27, 2007, is heading into the asteroid belt, where it will take lengthy close-up views of two asteroids: Ceres and Vesta. The dwarf planet Ceres ranks as the biggest asteroid, holding about one-third of the entire asteroid belt's mass. Vesta has a highly reflective surface and appears brighter than any other asteroid. Both likely finished forming within the solar system's first 10 million years. In contrast, Mars probably took 30 million years to form and Earth some 50 million. The asteroid Eros, which the NEAR-Shoemaker spacecraft visited in 2000 and 2001, appears to be a fragment of a larger body.

Dawn moved a step closer to its targets February 17 when it flew just 340 miles (550 kilometers) above Mars' surface and received a significant gravity assist. The spacecraft went into safe mode shortly after the flyby, so it didn't gather as much information as mission scientists had hoped. Engineers quickly diagnosed the problem, however, and Dawn is back to the picture of health.

Dawn's ion propulsion system is now taking it to Vesta. It will arrive in August 2011, eventually settle into orbit, and remain there for 9 months. It will then head off to Ceres, arriving in February 2015 and staying at least 5 months. While circling the two asteroids, Dawn will image their surfaces, investigate their internal structures, and record their compositions, all in an attempt to understand the solar system's earliest stages.

Vesta has an average diameter of about 315 miles (510 km) and rotates on its axis once every 5.3 hours. It appears to have a bone-dry basaltic surface — frozen lava that likely oozed out of the asteroid's hot interior shortly after its birth.

Vesta's main surface feature, deduced from Hubble Space Telescope observations, is a huge crater some 285 miles (460 km) across and 8 miles (13 km) deep at the asteroid's south pole. The crater's rim rises 2.5 to 7.5 miles (4 to 12 km) above the nearby terrain. The collision that gouged this crater blasted out 1 percent of Vesta's volume. The pieces entered their own orbits around the Sun, and some likely hit Earth. Astronomers estimate that perhaps 5 percent of all meteorites on Earth originated from this ancient collision.

Ceres measures about 590 miles (950 km) across and is big enough that its gravity makes it nearly spherical — the reason astronomers decided in 2006 to call Ceres a "dwarf planet." Planetary scientists think Ceres contains a significant fraction of water or ice beneath its rocky crust. If so, the surface could be coated with pockets of frost.

Answers to this and other questions about the solar system's formation and evolution should come into better focus after Dawn explores the asteroid belt's most intriguing members. **— R. T.**

Cool biochemistry

Planet-forming disks of dust and gas appear to contain a different soup of prebiological chemicals than Sun-like stars, scientists reported April 10 in *The Astrophysical Journal*.

NASA/ESA/The Hubble Heritage Team (STScI/AURA)

Cosmic drip. The interacting group of galaxies known as Arp 194 features many newly formed stars and a stream of material more than 100,000 light-years long.

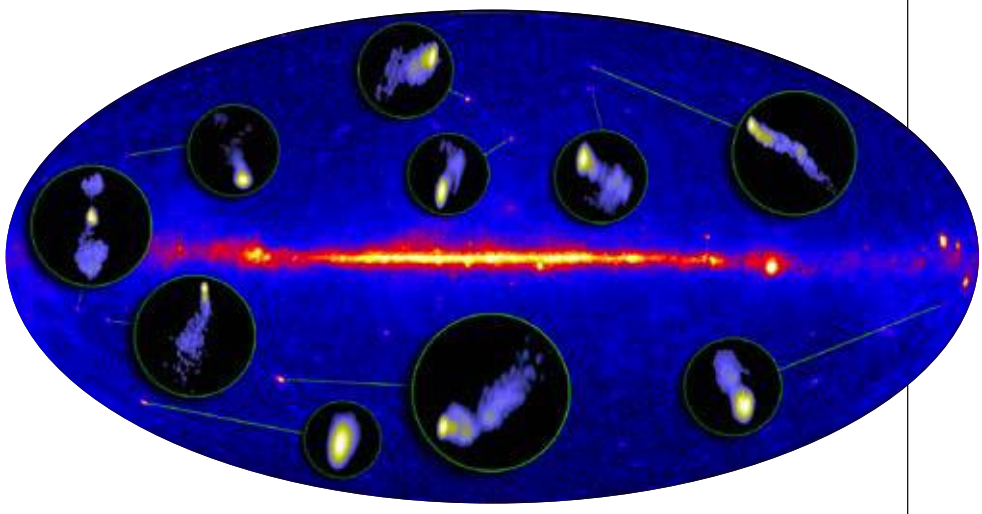
Twisting the night away

In 19 years of observing an often-violent cosmos, the Hubble Space Telescope has rarely found a scene as chaotic as Arp 194. This interacting group contains several galaxies and, most noticeably, a bright blue stream of stars, gas, and dust that stretches for more than 100,000 light-years.

Arp 194 lies some 600 million light-years from Earth in the constellation Ursa Major. It took Hubble's sharp eye to resolve this group's various interactions. Dust-rich spiral arms and luminous blue star clusters dominate Arp 194's northern component (at upper left in the image). The distorted shapes of the northern component arise from the ongoing collision of two galaxies, whose yellowish nuclei appear connected and in the early stages of merging. A relatively normal spiral galaxy lies to their right.

The collision compressed huge gas clouds, which stoked the fires of star formation and produced the long stream. It glows blue because it contains many massive star clusters filled with hot young stars.

At first glance, this material seems to form a bridge to Arp 194's southern component. But the image shows that the stream lies in front of the southern galaxy because its dust appears in silhouette. Hubble researchers released this image April 21 to mark the 19th anniversary of the space telescope. — **R. T.**



Matching up. Active galaxies' radio jets (zoomed-in images within circles) correlate to patches of high-energy gamma rays (orange-yellow patches) on NASA's Fermi Gamma-ray Space Telescope's map of the gamma-ray sky. NASA/DOE/Fermi LAT Collaboration and NRAO/AUI/MOJAVE Team/M. Kadler

Black hole jets observed in new light

An international team of astronomers solidified a long-standing theory about jets emanating from supermassive black holes at the centers of active galaxies. It found that the most powerful jets produce both low-energy radio waves and high-energy gamma rays. The team published two reports about its study in the May 1 issue of *The Astrophysical Journal Letters*.

All massive galaxies harbor central supermassive black holes surrounded by disks of stars, gas, and dust. Astronomers think that as disk material falls toward the black hole, magnetic fields can focus the matter into jets perpendicular to the disk. Astronomers observe radio emission from these jets and for years have theorized that the jets also emit higher-energy radiation.

Data from various high-energy satellites have hinted at this correlation. Observations from both NASA's Compton Gamma-ray Observatory in the 1990s and more recently the Chandra X-ray Observatory have pointed toward the link.

Using NASA's Fermi Gamma-ray Space Telescope and the Very Long Baseline Array (VLBA) of 10 radio telescopes spread out between Hawaii and the U.S. Virgin Islands, astronomers observed gamma-ray radiation associated with the radio jets. With the VLBA's resolution, "We see the innermost few hundred light-years of these jets for even the most distant active galaxies seen by Fermi," says Yuri Kovalev, lead author on one of the papers.

While the team can't say that both types of radiation came from the exact same region, they "concluded that gamma-ray flares come from locations close to the base of the radio jets," Kovalev says. — **L. K.**

HomeDome/ProDome

Two PD10's in France

- True Rotating Dome
- Easy Assembly
- 6, 10, 15ft. Diameter
- All Fiberglass
- Motors & Automation
- Wide Slot Openings
- Complete Systems Priced from $3150

DomeLease
A new approach to acquiring an affordable observatory
www.domelease.com

Technical Innovations, Inc.
7851 Cessna Ave., Gaithersburg, MD 20879
E-mail: domes@homedome.com
Ph: 301-977-9000 • Fax: 301-977-1106

FREE BROCHURE
www.homedome.com • www.robofocus.com

Space tornados Tornado-like swirls of hot gas generate electrical currents up to 100,000 amperes to power aurorae, NASA scientists reported April 23.

Rocky road. Gliese 581 e (foreground in this illustration) has a mass just 1.9 times Earth's, making it the smallest exoplanet yet discovered around a normal star. Along with three other known planets, it orbits the red dwarf Gliese 581. ESO/L. Calçada

A near-Earth-sized exoplanet discovered

Finding an Earth-mass planet orbiting a normal star has long been the holy grail of exoplanet researchers. The quest now seems closer to reality than ever before.

On April 21, Michel Mayor of the Geneva Observatory announced the discovery of a planet with just 1.9 times Earth's mass. The new planet orbits Gliese 581, a red dwarf star located 20.5 light-years away in the constellation Libra the Scales. Dubbed Gliese 581 e (because it's the fourth planet known in this system), it revolves around its host star in just 3.15 days at a distance of 2.8 million miles (4.5 million kilometers).

Mayor's team thinks Gliese 581 e is likely a rocky planet. Unfortunately, it lies too close to its star to be in the habitable zone — the region around any star where water could exist as a liquid.

This isn't true of the outermost planet known in this system. New observations allowed the team to refine 7 Earth-mass Gliese 581 d's orbit. It lies 20 million miles (33 million km) from the star — inside the red dwarf's habitable zone. "Gliese 581 d could be covered by a large and deep ocean — it is the first serious 'water world' candidate," says team member Stephane Udry of the Geneva Observatory.

The astronomers found the new world by measuring changes in Gliese 581's velocity induced by the planet's gravitational tug. Gliese 581 e caused a tiny wobble of just 4 mph (7 km/h) — the pace of a brisk walk. **— R. T.**

A gathering storm

The telltale signs of airborne dust appeared in Mars' atmosphere in mid-March. The storm first appeared in the Hellas basin, a huge impact feature in the planet's southern hemisphere, and soon spread northward. By mid-April, the growing storm had cut the amount of sunlight reaching the surface and reduced the power available to the twin rovers currently operating there.

Such storms happen fairly regularly on the Red Planet. They usually arrive around the time Mars reaches its closest point to the Sun. That happened April 21, so at least the potential for a storm caught no one by surprise. Planetary scientists don't know how widespread the storm might grow, but occasionally such systems envelop the whole planet.

Any major dust storm will adversely affect the five spacecraft currently at Mars. The three orbiting craft — Mars Reconnaissance Orbiter, Mars Odyssey, and Mars Express — can't clearly image the surface.

The Spirit and Opportunity rovers both rely on solar panels to convert sunlight to electricity. As of mid-April, Spirit's power was down 20 percent and Opportunity's 30 percent. **— R. T.**

BRIEFCASE

How asteroids get their color

Astronomers found that the harsh space environment reddens an asteroid's surface within 1 million years. They determined that only the Sun's wind of high-energy particles could redden the surface that quickly. The astronomers' finding appeared in the April 23 issue of *Nature*. — L. K.

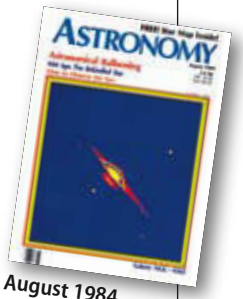
A lot more going on in Orion

The Orion Molecular Cloud is a chaotic and crowded stellar nursery, astronomers say. They observed the region — spanning more than 20 times the angular size of the Full Moon — in infrared and radio radiation to pierce the dust. On April 20 at a meeting of the Royal Astronomical Society, the astronomers presented their large-scale study of the young stars and the jets emanating from many of those stars. — L. K.

Blob at the cosmic dawn

Researchers spotted a giant blob of gas dating to only 800 million years after the Big Bang. This marks the most distant and therefore earliest such object observed. The blob spans 55,000 light-years, which is comparable to a modern-day galaxy. The study appeared in the May 10 issue of *The Astrophysical Journal*. — L. K.

25 years ago in *Astronomy*



August 1984

In the August 1984 issue of *Astronomy*, infrared astronomer Sten Odenwald gave a behind-the-scenes description of scientific observing in "Astronomical ballooning." Because water vapor in Earth's atmosphere blocks infrared radiation, infrared astronomers need to get their instruments as high up as possible.

Odenwald discussed the advantages of using balloons compared with high-altitude telescopes and spacecraft. One key advantage of ballooning over a spacecraft launch is that "the cycle time for making a flight, reducing the data, and preparing for a new flight is short enough that you can make several flights a year," wrote Odenwald. This saves both time and money.

August 1999

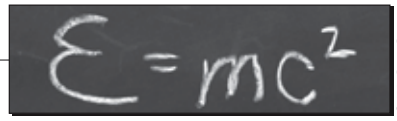
10 years ago in *Astronomy*

In the August 1999 issue of *Astronomy*, frequent contributor James Oberg wrote about spacecraft gravity assists. In "The spacecraft's got swing," Oberg described the Earth swing-by that the Cassini spacecraft needed to alter its course and give it speed to reach the outer solar system.

Oberg gave a history of gravity assists — from the mathematical expectations laid out in the 1960s to the first Grand Tour of the solar system completed in 1989. Oberg also explained how gravity assists work.

While such swing-bys greatly increase a craft's path distance, they also provide the energy equivalent to tons of fuel. "The price paid for gravity assists is usually mission complexity," wrote Oberg. But until engineers develop more high-efficiency engines, gravity assists are a good way to get the craft where it needs to go. **— L. K.**

Einstein Deciphered the Puzzles of the Universe for Every Scientist in the World. Isn't It about Time Someone Deciphered Them for You?



© 2007 JupiterImages Corporation.

At last ... secrets of modern physics taught in language you can understand. These recorded lectures let you learn at your own rate, wherever and whenever you wish!

Now you can learn the basic ideas behind Einstein's theories of relativity and quantum physics from 24 vibrant, expertly delivered lectures that require no special background in math or science.

Professor Richard Wolfson has a gift for explaining the awe-inspiring concepts of modern physics in ways that anyone interested in learning can readily master.

The 20th century brought two revolutionary changes in our understanding of the physical universe. Relativity and quantum theory touch the very basis of physical reality, altering our commonsense notions of space and time, cause and effect.

Time Travel, Black Holes, and the Raisin That Lit New York

Is time travel into the future possible? Yes—but if you don't like what you find, you can't come back! Does a single raisin contain enough energy to power New York City for a day? Absolutely! Do black holes and wormholes exist? Quite possibly! Is the universe governed by laws that strictly predict what will happen in the future, or by chance? In part, by chance. These and other consequences flow from relativity and quantum physics.

The Theory of Relativity in One Sentence?

The basic ideas of relativity and quantum physics can be mastered by anyone. Einstein's theory of relativity, for example, can be stated in a concise English sentence.

In **Einstein's Relativity and the Quantum Revolution: Modern Physics for Non-Scientists, 2nd Edition**, Professor Wolfson shows how inquiry into matter at the atomic and subatomic scales led to quandaries that caused even the great physicist Werner Heisenberg to wonder: Can "nature possibly be as absurd as it seems to us in these atomic experiments?"

You will see how these quandaries are resolved by quantum mechanics. Professor Wolfson explains the basics of quantum theory and explores the "zoo" of particles and forces that compose everything.

About Your Professor

Dr. Richard Wolfson (Ph.D., Dartmouth College) is Professor of Physics at Middlebury College in New England. Decades of teaching at Middlebury, with its strong emphasis on the humanities, have made him an expert at demonstrating the logic and significance of physics to students from many fields. His writings have appeared in *Scientific American*. He is author of *Physics for Scientists and Engineers*.

About The Teaching Company

We review hundreds of top-rated professors from America's best colleges and universities each year. From this extraordinary group we choose only those rated highest by panels of our customers. Fewer than 10% of these world-class scholar-teachers are selected to make The Great Courses®.

We've been doing this since 1990, producing more than 3,000 hours of material in modern and ancient history, philosophy, literature, fine arts, the sciences, and mathematics for intelligent, engaged, adult lifelong learners. If a course is ever less than completely satisfying, you may exchange it for another or we will refund your money promptly.

Lecture Titles

1. Time Travel, Tunneling, Tennis, and Tea
2. Heaven and Earth, Place and Motion
3. The Clockwork Universe
4. Let There Be Light!
5. Speed *c* Relative to What?
6. Earth and the Ether—A Crisis in Physics
7. Einstein to the Rescue
8. Uncommon Sense—Stretching Time
9. Muons and Time-Traveling Twins
10. Escaping Contradiction—Simultaneity Is Relative
11. Faster than Light? Past, Future, and Elsewhere
12. What about $E=mc^2$, and Is Everything Relative?
13. A Problem of Gravity
14. Curved Spacetime
15. Black Holes
16. Into the Heart of Matter
17. Enter the Quantum
18. Wave or Particle?
19. Quantum Uncertainty—Farewell to Determinism
20. Particle or Wave?
21. Quantum Weirdness and Schrödinger's Cat
22. The Particle Zoo
23. Cosmic Connections
24. Toward a Theory of Everything

THE TEACHING COMPANY®
The Joy of Lifelong Learning Every Day™
GREAT PROFESSORS, GREAT COURSES, GREAT VALUE GUARANTEED.™

About Our Sale Price Policy

Why is the sale price for this course so much lower than its standard price? Every course we make goes on sale at least once a year. Producing large quantities of only the sale courses keeps costs down and allows us to pass the savings on to you. This approach also enables us to fill your order immediately: 99% of all orders placed by 2 pm eastern time ship that same day. Order before August 28, 2009, to receive these savings.

SAVE UP TO $185
OFFER GOOD UNTIL AUGUST 28, 2009

1-800-TEACH-12 (1-800-832-2412)
Fax: 703-378-3819

Special offer is available online at
www.TEACH12.com/8astr

The Great Courses®
THE TEACHING COMPANY®
4151 Lafayette Center Drive, Suite 100
Chantilly, VA 20151-1232

Priority Code 33355

Please send me **Einstein's Relativity and the Quantum Revolution: Modern Physics for Non-Scientists, 2nd Edition**, which consists of twenty-four 30-minute lectures plus Course Guidebooks.

- ☐ **DVD $69.95** (std. price $254.95) **SAVE $185!** plus $10 shipping, processing, and lifetime satisfaction guarantee.
- ☐ **Audio CD $49.95** (std. price $179.95) **SAVE $130!** plus $10 shipping, processing, and lifetime satisfaction guarantee.
- ☐ **Audiotape $34.95** (std. price $129.95) **SAVE $95!** plus $10 shipping, processing, and lifetime satisfaction guarantee.
- ☐ **Check or Money Order Enclosed**

* Non-U.S. Orders: Additional shipping charges apply. For more details, call us or visit the FAQ page on our website.

** Virginia residents please add 5% sales tax.

Charge my credit card:

☐ VISA ☐ MasterCard ☐ Discover ☐ American Express

ACCOUNT NUMBER _____ EXP. DATE _____

SIGNATURE _____

NAME (PLEASE PRINT) _____

MAILING ADDRESS _____

CITY/STATE/ZIP _____

PHONE *(If we have questions regarding your order—required for international orders)* _____

☐ **FREE CATALOG.** Please send me a free copy of your current catalog no purchase necessary).

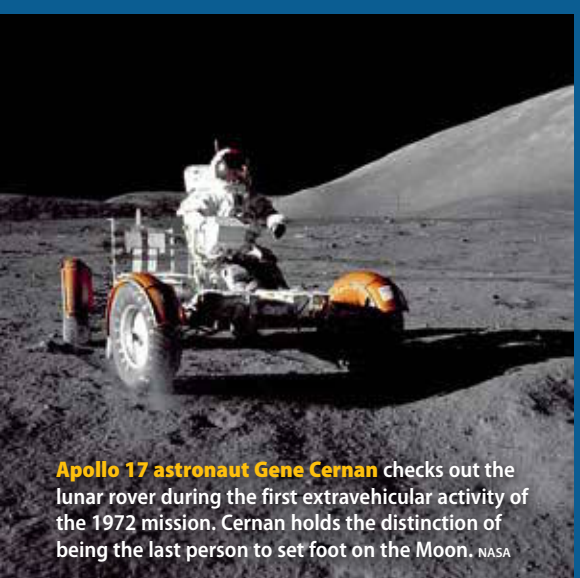
Special offer is available online at www.TEACH12.com/8astr
Offer Good Through: August 28, 2009

Apollo on steroids

How we'll return to the Moon

Four decades after the first human landing, we stand on the threshold of a second grand adventure.

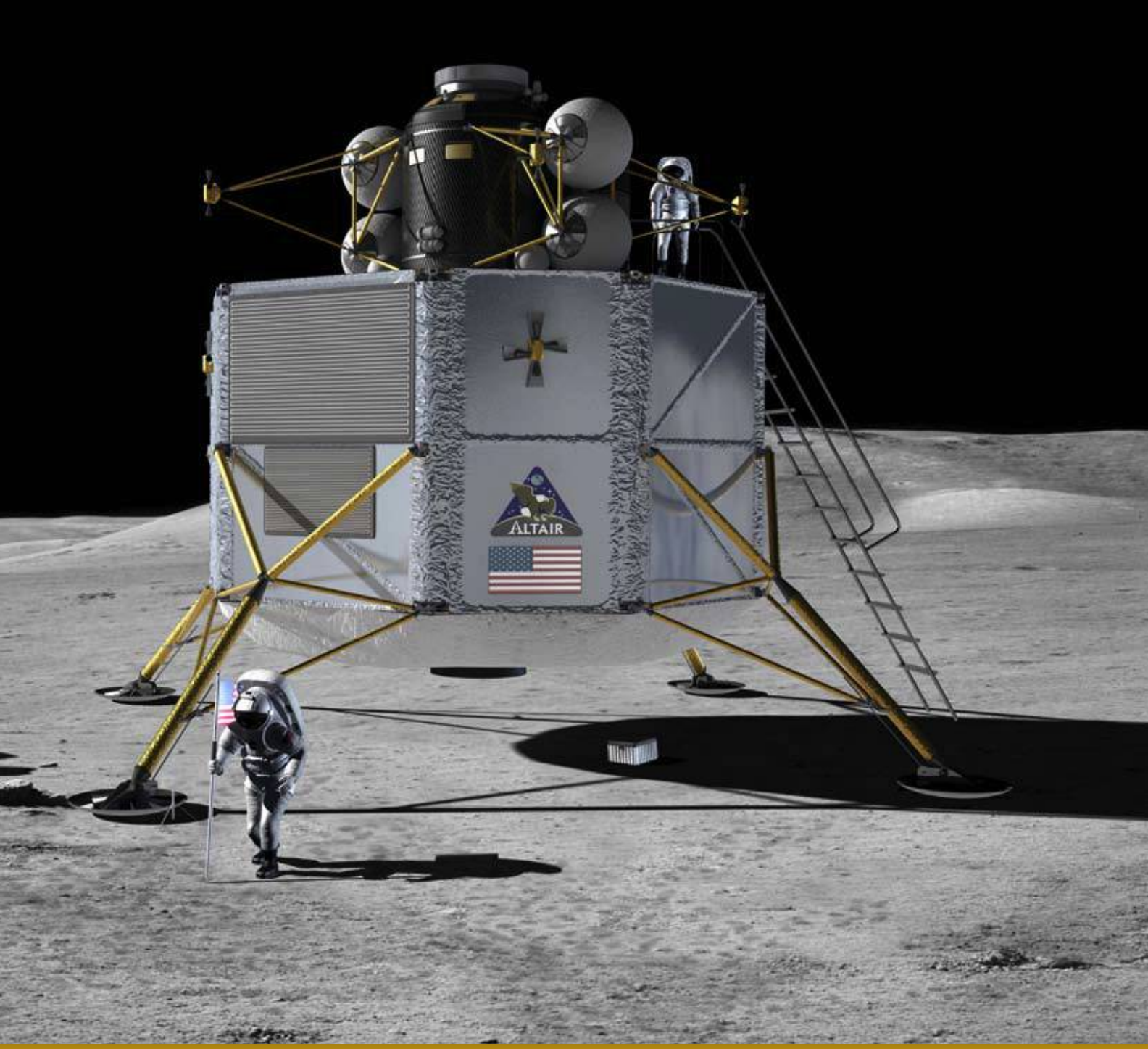
by James Oberg



Apollo 17 astronaut Gene Cernan checks out the lunar rover during the first extravehicular activity of the 1972 mission. Cernan holds the distinction of being the last person to set foot on the Moon. NASA

∧ An Altair lunar module rests on the Moon as its crew begins to explore the lunar surface. These initial missions, called "lunar sorties," could fly as early as 2020. The Altair lander dwarfs the Apollo lunar modules and will deliver as many as four astronauts anywhere on the Moon. NASA

< The Ares V booster will be NASA's new heavy-launch vehicle. It will send Altair — along with up to 100,000 pounds (45,000 kilograms) of cargo — to the Moon. Humans starting their journey to the Moon must first reach low Earth orbit aboard the smaller Ares I rocket. NASA



The history books record July 20, 1969, as the day Neil Armstrong planted the first human foot on the Moon. History doesn't make as big a deal about December 14, 1972. On that day, astronaut Gene Cernan lifted his foot back onto Apollo 17's lunar module, ending the first wave of human exploration of the Moon with the promise, "We shall return."

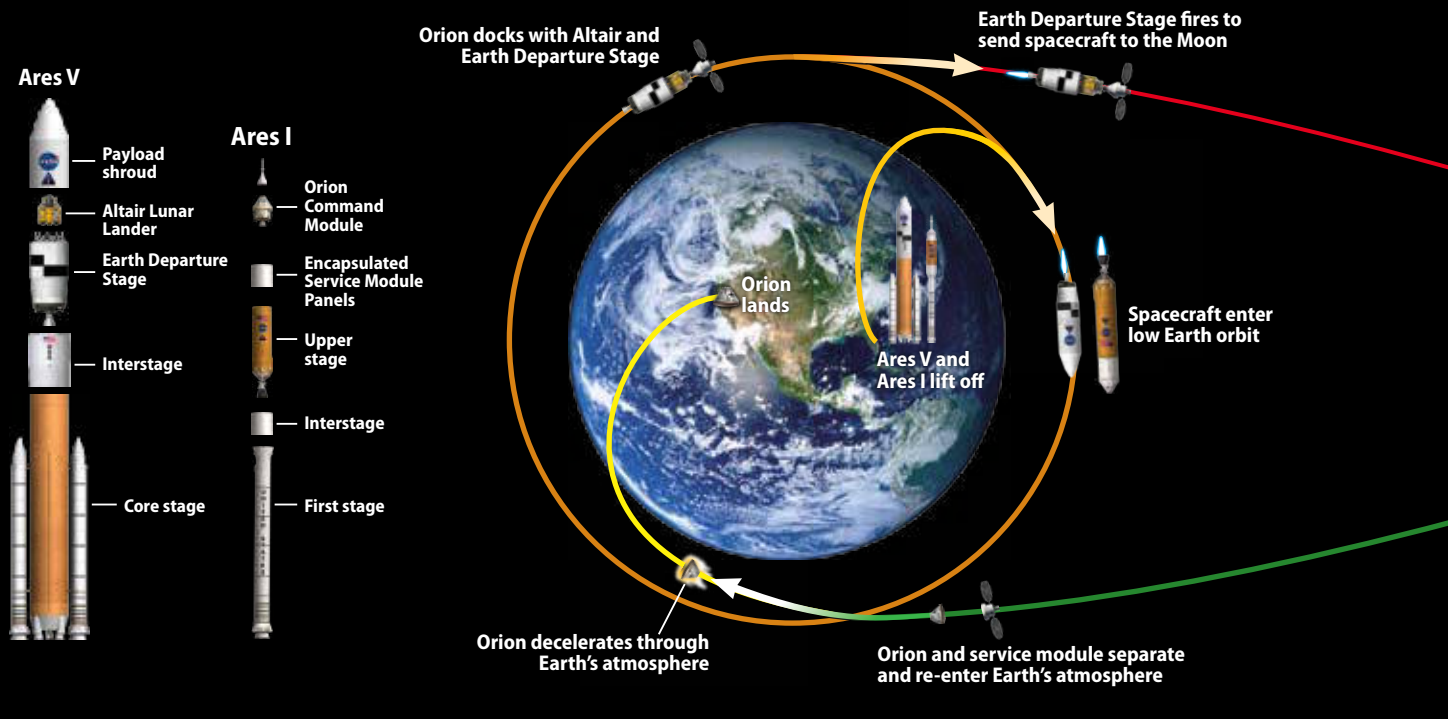
Now, more than a generation later, the reality of that new exploration has begun to solidify. If all goes according to plan and funding levels stay strong, NASA hopes to make the next lunar landing around 2020 — 50 years after Apollo. The Obama administration recently blessed the space vehicles and flight procedures now under advanced development.

We'll go back with systems that bear a superficial resemblance to the tried-and-true Apollo hardware. Yet these similarities obscure vast improvements NASA is forging. The most obvious changes are ones of scale. Many observers describe the new systems as "Apollo on steroids." The new lunar lander — named "Altair" — will take four crewmembers to the surface rather than Apollo's two. And the new command module — named "Orion" — will orbit the Moon on autopilot instead of leaving one person aboard.

Not your grandfather's moonship

The new designs reflect the hindsight of 40 years and across-the-board technological advances during that period. Strategic planning also has changed. The new lunar landing is not an end in itself, but one plateau in an ascending ladder of goals.

It's true that "the landing profile will remain essentially unchanged," says



program official John Connelly of NASA's Johnson Space Center in Houston, "but that's not due to lack of consideration of alternatives." In a series of intensive symposiums during the past 2 years, NASA engineers evaluated a wider range of strategies than even imaginable in 1961.

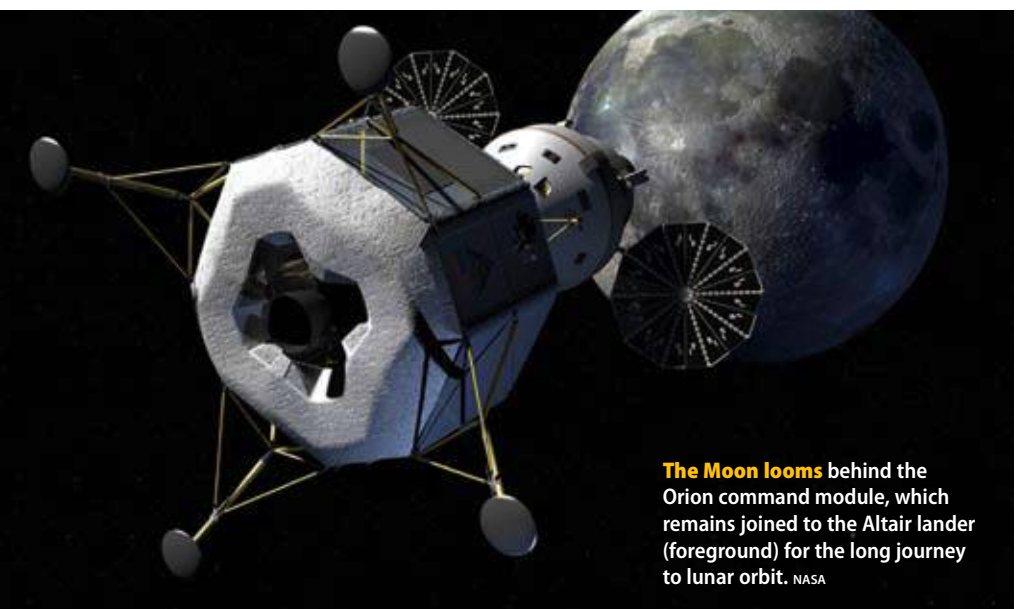
They included staging the landings through lunar Lagrange points, locations in space where the gravitational pulls of Earth and the Moon balance. This technique would have allowed lunar landings and liftoffs at any time, breaking from the precisely timed launch windows Apollo had to use. In the end, parking the Earth-return crew module in low lunar orbit and descending in a separate vehicle won out.

But what a new descent vehicle NASA devised. The Apollo lunar module, for example, carried two men to the surface with minimal equipment. It could land only in a swath across the low latitudes of the Moon's visible face and could remain on the surface for only a few days at most. The cabin the crew ate and slept in also served as the airlock, and abrasive lunar dust rapidly contaminated it. According to Apollo program space suit designer Joe Kosmo, "The suits were breaking down with jammed joints and leaky seals after only a few days."

NASA built the Apollo lander for quick dash-and-grab missions. Still, it was just barely within the capabilities of the most stretched state of the art on the planet. The lander couldn't simply be beefed up or reinforced; it had to be redesigned from scratch, and it has been.

Program engineer Kriss Kennedy says the new lunar lander has greatly expanded capabilities made possible by tripling its weight from Apollo days to 100,000 pounds (45,000 kilograms). It also uses a new generation of crew systems, which includes "a separate airlock attached to the descent stage," adds Kennedy.

For reliability, the propellants in the ascent stage will still be "hypergolics" — chemicals that can be stored at room temperature and ignite on contact with each other. The landing stage, however, will use high-energy, low-temperature fuels. These offer an added advantage because they can be used as resources for extending a mission once on the lunar surface.



The Moon looms behind the Orion command module, which remains joined to the Altair lander (foreground) for the long journey to lunar orbit. NASA

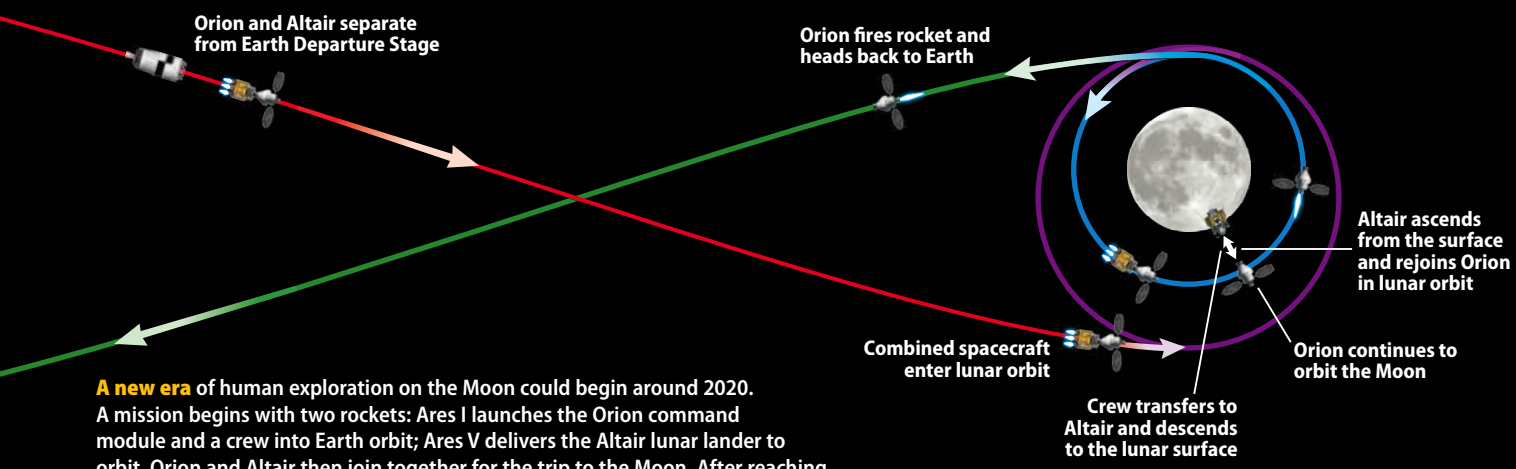
Altair to the Moon

NASA expects the new design to greatly expand what astronauts will be able to do on the Moon. In mid-2008, Connolly's team developed a catalog of Design Reference Missions (DRMs) that specifies the sorts of missions Altair must perform.

First up: a simple "lunar sortie." This type of mission could land anywhere on the Moon and would stay on the surface

A NASA "rocket scientist" from 1975 to 1997, **James Oberg** *currently works as a space consultant for NBC News.*

Journey to the Moon


Orion and Altair separate from Earth Departure Stage
Orion fires rocket and heads back to Earth
Altair ascends from the surface and rejoins Orion in lunar orbit
Combined spacecraft enter lunar orbit
Orion continues to orbit the Moon
Crew transfers to Altair and descends to the lunar surface

A new era of human exploration on the Moon could begin around 2020. A mission begins with two rockets: Ares I launches the Orion command module and a crew into Earth orbit; Ares V delivers the Altair lunar lander to orbit. Orion and Altair then join together for the trip to the Moon. After reaching lunar orbit, Altair takes all the astronauts to the surface while Orion continues to orbit. After the excursion, Altair and Orion rejoin for the trip home. *Astronomy*: Roen Kelly

The Orion command module (left) separates from the Altair lander in lunar orbit as the crew starts its descent. The unmanned Orion will remain in orbit while the astronauts explore the surface. NASA

A pair of rovers transports these astronauts to a remote location so they can set up a science experiment. Each rover will carry two crew members, although it can hold up to four in an emergency. NASA

about a week. The Altair lander would carry everything the crew would need for the mission. The report further states, "This mission enables exploration of high-interest sites, scouting of Lunar Outpost locations, technology development objectives, and the capability to perform EVAs [extravehicular activities]." These lunar sorties are the missions NASA plans to launch by about 2020.

NASA will design Orion's lunar orbit so Altair can reach a wide variety of sites. Unlike Apollo, these sites could be on the Moon's farside as well as the near and anywhere from equator to pole. Reaching more difficult locations, such as those near the poles, would require narrow launch windows from Earth and the ability to loiter in lunar orbit for several days either before or after the surface excursion.

The second type of trip involves a no-crew cargo lander. According to this trip's DRM, these missions would support a lunar outpost, deliver supplies to help build one, or merely position assets for a subsequent sortie lander. The vehicle could land anywhere on the Moon and would carry between 31,000 and 37,500 pounds (14,000 and 17,000 kg) of equipment or other supplies to the surface.

The third and fourth types of missions will land astronauts at a lunar outpost either as visitors (mission 3) or residents (mission 4). In both mission types, the crew would be able to extend its stay by using assets at the outpost and not have to rely solely on the lander's resources.

The "resident missions" achieve a top goal of U.S. space policy — a sustained human presence on the Moon. In much the same way as the International Space Station remains inhabited, crews likely would stay at the lunar outpost for up to 6 months and then return to Earth when another crew arrives to replace them. Although NASA has set no timeline for establishing a continuous presence on the Moon, the space agency hopes to do so as soon as possible after the first lunar sorties.

The Orion command module circles the Moon with no crew aboard while astronauts explore the lunar surface for as much as a week at a time. NASA

Altair's ascent stage needs to climb approximately 60 miles (100 kilometers) before its crew can rendezvous with the unmanned Orion in low lunar orbit. NASA

Altair's ascent module (left) prepares to dock with Orion after a crew's weeklong exploration on the surface. Altair looks much smaller now after leaving its bulky descent stage behind. NASA

Another new element of mission design involves international partners. Such arrangements were minimal during Apollo but became crucial for the International Space Station. For now, NASA plans for the United States to develop its own independent spaceflight infrastructure but take on international partners to enhance the research, habitats, and other activities at the route's lunar end. Europe, Japan, Canada, India, and China have expressed interest.

Furthermore, other nations may develop their own human access to lunar orbit and, possibly, the lunar surface. Such capabilities would complement the U.S. program and provide welcome contingency plans for rescues if needed.

A better spacecraft

Some mission requirements have major consequences for the new hardware. Consider the automated missions needed to deliver cargo to the Moon and follow the engineering chain this instigates.

In such a mission, NASA will launch the Altair lander aboard an Ares V booster, a Saturn V equivalent now under development. Altair doesn't wait in low Earth orbit for a manned Orion command module to join it — it heads right out for the Moon.

Because Altair lies under the payload shroud — "on top of the stack," as rocket scientists say — its volume isn't limited like Apollo's lunar module was. This freedom allows Altair to use liquid hydrogen as its fuel, which is 50 percent more efficient than Apollo's hydrazine fuel. Because liquid hydrogen is less dense than hydrazine, however, it's bulkier, and that makes the fuel tanks several times bigger. Yet by launching Altair on its own booster, that's not a problem — the engineers simply stretch the shroud a bit.

Once on the lunar surface, with either a cargo canister or, for a crew-carrying mission, an ascent stage and separate airlock, these bulkier tanks confront operators with a challenge. The extra volume puts the payload a lot higher above the surface. For a crew, this requires a ladder perhaps 3 times longer than Apollo's. And for cargo, it requires a small derrick to offload the equipment. Fortunately, the cargo weighs only one-sixth of what it does on Earth thanks to the Moon's lower gravity.

But after the crew accomplishes these tasks, the fuel tanks' large volumes stop being a hindrance and magically become a benefit. First, the tanks will have a lot of leftover propellants. Liquid hydrogen and liquid oxygen not only burn well in rocket engines, but they also react energetically in fuel cells at the base power plant or in surface rovers. Second, after the astronauts empty this bonus cargo, the well-insulated tanks will be available for use by the growing base, either as habitats (they never held anything toxic) or receptacles for volatiles derived from the lunar surface.

And a better space suit

Probably the most critical piece of gear on the lunar surface (aside from Altair's

As the mission ends, Orion jettisons its service module and hits Earth's upper atmosphere. In a few minutes, the astronauts will be back on terra firma. NASA

The first lunar outpost will be big enough to house four astronauts for up to 6 months at a time. When a new crew arrives, the replaced occupants will head back to Earth in much the same way as astronauts on the International Space Station now rotate in and out. NASA

ascent stage, of course) is the space suit. During the Apollo missions, the harsh lunar environment — and in particular the unexpectedly abrasive lunar dust — savaged the suits and on some occasions brought them dangerously close to failure.

The new Moon suits, according to program engineer Laura Kerney, will be built with more advanced components. They will be lighter, stronger, more durable, and have smarter command, control, display, and self-test capabilities. "They will be able to 'buddy up' with another suit or with consumable supplies on rovers or at servicing ports on the exterior of the base itself," she explains.

But their most important property will be their design. "From the start, the systems will be built for servicing on the Moon," Kerney explains. This isn't just a matter of swapping batteries or adjusting mechanical settings; it's a fundamental feature engineers learned through experience on the International Space Station. They will minimize the number of tools needed and the variety of spare parts. (For example, they will be built with three types of valves instead of Apollo's twelve.) They'll make the internal parts hard to lose or, if they are lost, easy to find. Modular suits also can be cannibalized. And the suits will degrade gracefully so they break down in stages and not all at once.

Nobody knew how to build such suits during Apollo. The ones the first lunar astronauts used were adequate for only the briefest sorties outside the lunar landers. Most engineers did not even suspect the need for suits that could be serviced on-site until they studied Apollo results and gathered experience from both American and Russian space stations. Obvious only in hindsight, the new design approaches demonstrate critical advances in far more than mere hardware.

Heading back home

Returning from the Moon, at least in the beginning, will look much the same as Apollo's flight plan. Yet major changes lurk beneath the superficial similarity. Because the astronauts have been exploring the Moon for weeks or months, they will have to retrain in critical flight procedures. The skills they learned on Earth will have grown rusty while on the Moon.

Their ticket home awaits them in low lunar orbit: the Orion command module. Because no one has been on board, mission operators on Earth will have to remotely verify Orion's operational health before the crew launches from the lunar surface. If any doubt exists about the vehicle's usability, the crew can stay put. And, if needed, extra supplies can be sent from Earth on smaller rockets.

This idea may be the most profound conceptual evolution of future lunar exploration — no longer will being stuck on the Moon mean certain death. Instead, staying on the surface would be the preferred solution over trying to get back to Earth in questionable hardware.

Mission designers call this the "abort-to-surface" philosophy. During the initial landing, or during the concluding launch to the waiting Orion command module, hardware problems could arise that prevent a safe mission.

After astronauts deploy enough infrastructure on the Moon, however, crews in these situations could be better off if they divert to safe surface facilities or facilities that could be made safe with quick resupply drones from Earth.

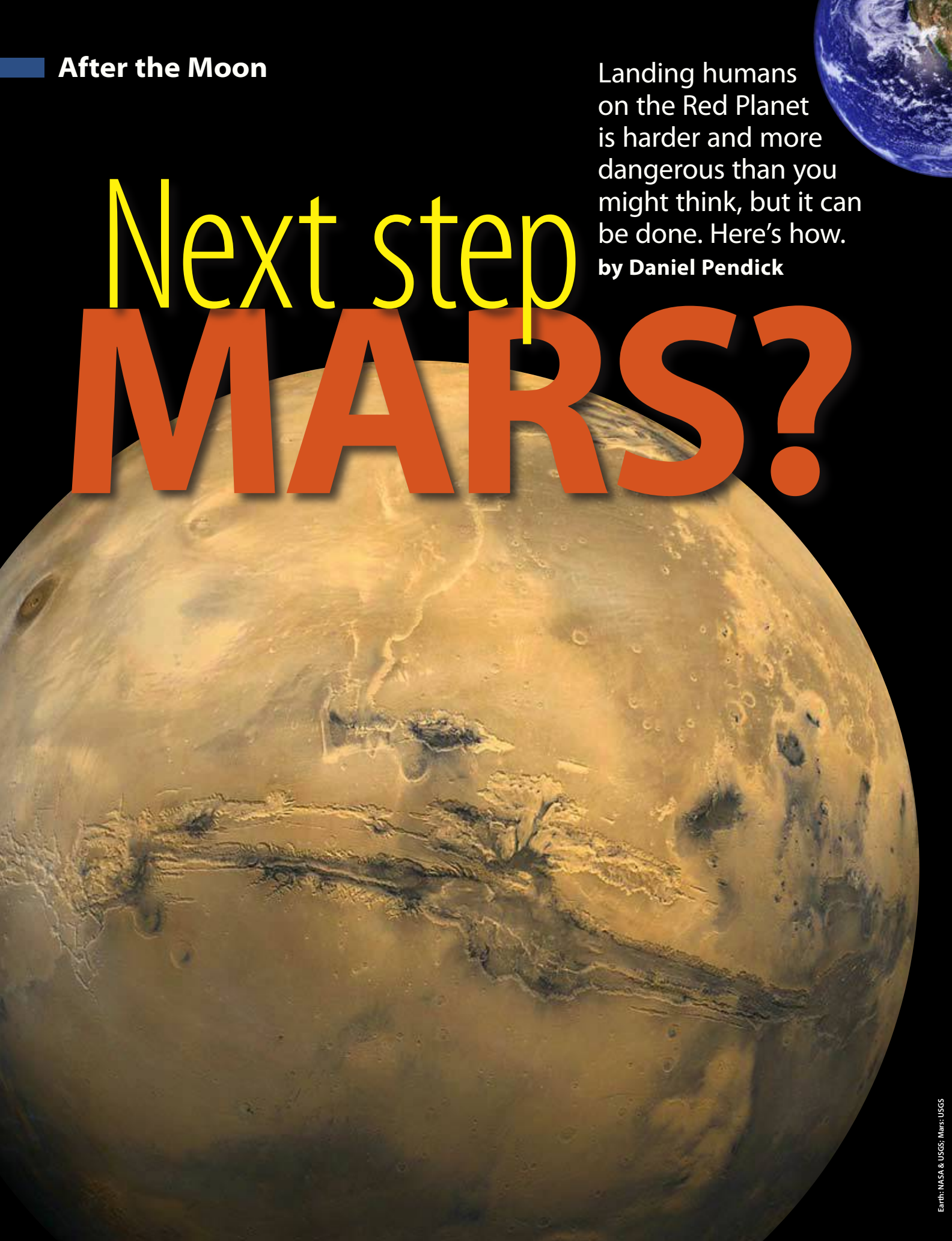
At this stage, the Moon will still be a hideously dangerous place. But seeking emergency shelter there would not be a doomed gamble. As NASA develops the robust systems needed for this next wave of human exploration, the Moon no longer will be a distant novelty but instead a home away from home. Apollo was only the first step — the other Moon boot is getting ready to drop.

To see an animation of a lunar mission from launch to splashdown, visit www.Astronomy.com/toc.

Next step MARS?

Landing humans on the Red Planet is harder and more dangerous than you might think, but it can be done. Here's how.

by Daniel Pendick



Earth: NASA & USGS; Mars: USGS

Sending astronauts to explore Mars could be the toughest trip in the history of the human race. Four to six people will live in an aluminum can for up to 6 months on the way to the Red Planet. After a harrowing descent to the surface, the crew will continue to live in cramped habitats for as many as 600 days until Earth reaches the spot in its orbit that will make a homebound journey possible. Finally, the intrepid explorers will blast off from the martian surface only to ride yet another aluminum can back to Earth for 6 months. Their high-speed reentry into Earth's atmosphere — 2½ years since leaving home — will seem anticlimactic.

Lunar journeys include opportunities to abort the mission all along the process, from the launch pad to final approach. Not so for Mars. Once the mission leaves Earth, the crew is committed for the duration. Going to the Moon is like paddling a few miles outside of New York Harbor; going to Mars is like sailing onward to Europe in a barrel.

Tough trip, yes, but impossible? Advocates of Mars exploration think not. Given the money and the commitment to do it on par with the Apollo-era push to go to the Moon, some believe we could put footprints on Mars in a mere decade.

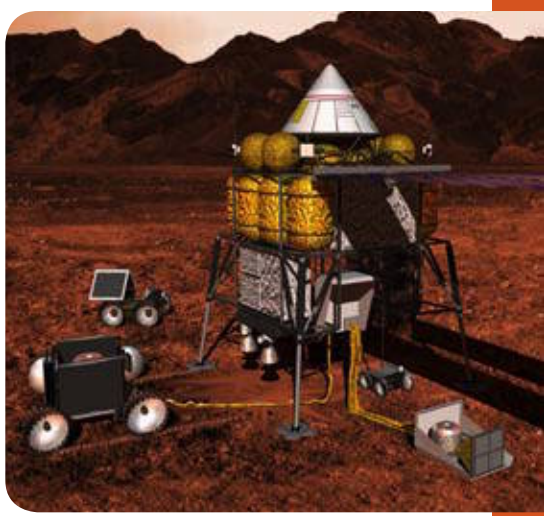
Why go to Mars?

There is no more passionate cheerleader for human Mars exploration than aerospace engineer Robert Zubrin. He is the founder and president of the Mars Society and author of a 1996 manifesto, *The Case for Mars: The Plan to Settle the Red Planet and Why We Must*. He also was the chief architect of Mars Direct, a mission design he says could get humans on Mars sooner and cheaper than anything NASA has proposed.

For Zubrin and like-minded people, putting footprints on Mars is not a question of whether, why, or how. It's ultimately a must. It's how we'll find out if life once existed, or still exists, on Mars. It will significantly advance aerospace technology and inspire the next generation. And it will expand humanity to another planet. "NASA needs a goal," Zubrin says. "The goal should be sending humans to Mars. Mars is where the science is. It's where the challenge is. It's where the future is. It is the new frontier."

Daniel Pendick *is an associate editor of* Astronomy.

A nuclear thermal rocket (NTR) stage could take astronauts from Earth orbit to Mars. An NTR uses a hot nuclear core to superheat rocket propellant, generating more thrust with less fuel than a chemical rocket engine. In this artist's concept, a separately launched crew vehicle from Earth has docked with the NTR and delivered astronauts to the habitat where they will live and work for 6 months on the way to Mars. Unless otherwise noted, Mars mission art courtesy John Frassanito & Associates, Inc.



A cargo ship sent to Mars 2 years before the crew departs would land supplies and hardware on the surface. This cargo lander is an automated chemical plant that transforms the martian atmosphere into fuel for the small conical spacecraft, the Mars Ascent Vehicle, mounted on top. At the end of the surface mission, astronauts would leave Mars' surface in the craft.

How do we get to Mars?

In spacecraft, of course. Thanks to Zubrin and NASA, hopeful interplanetary explorers can choose from a menu of options for human flights to Mars.

Science fiction is littered with massive spaceships that zip off to other planets as easily as driving to a convenience store for a gallon of milk. In real interplanetary flight, it won't work that way.

"Mars is where the science is. It's where the challenge is. It's where the future is. It is the new frontier."
— Robert Zubrin

Travel to Mars will include three steps. First, lift yourself and your ship from the bottom of Earth's gravity well. Second, accelerate on a trajectory to Mars. Third, descend into Mars' gravity well and land safely on the surface. It's not as easy as it sounds.

Rocket propellant is the problem. You must have enough to get you off Earth, to Mars, and back. The propellant always significantly outweighs the payload. In fact, it's best to visualize any interplanetary spacecraft as a massive gas tank with a tiny payload stuck to the front of it. A journey to Mars traversing hundreds of millions of miles requires a tremendous fuel supply.

One way around this dilemma is adopting a "split-mission strategy." It divides the plan into multiple stages to make the whole enterprise more manageable. The strategy has its roots in a speech President George H. W. Bush delivered in 1989 on the steps of the National Air and Space Museum in Washington, D.C.

On July 20 of that year, the 20th anniversary of the Apollo 11 Moon landing, Bush announced his Space Exploration Initiative. It called for construction of the space station, returning to the Moon, and, someday, going to Mars.

NASA launched the "90-Day Study" to flesh out Bush's vision. The Mars portion emerged as an elaborate "all-up" mission architecture. Astronauts would assemble a single massive ship at the space station. Upon arrival at Mars, the ship would split into a return vehicle to eventually take the crew home and an "excursion vehicle" to land the crew on the surface and return to orbit at the end of the expedition. This first mission would entail only 30 days on the surface.

Mars Direct is born

The price of Bush's initiative was estimated at $500 billion, and by 1990 his administration had all but abandoned it. But the episode did stimulate important progress. It spurred Zubrin, then working at Martin Marietta Astronautics, to develop the Mars Direct plan.

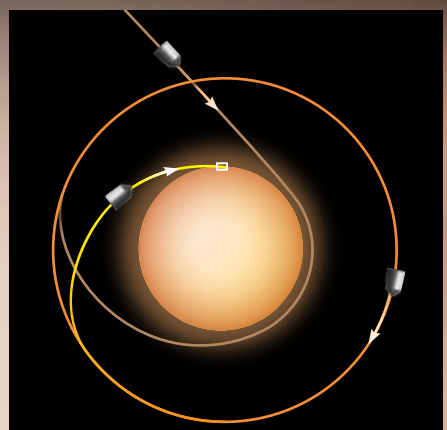
Zubrin was concerned that national "sticker shock" over Bush's proposed initiative would doom future human Mars exploration. He developed the Mars Direct concept with a colleague at Martin Marietta, David Baker. "It was apparent we needed a much quicker, cheaper plan, or there would be no program at all," Zubrin recalls.

How to land people on Mars

Proposals for human exploration of Mars require landing payloads of cargo and crew far too heavy for today's technology. Aerospace engineers have started to brainstorm new ways to slow down payloads entering the martian atmosphere at blistering speeds. One leading design relies on a device called a supersonic inflatable aerodynamic decelerator (SIAD). Its broad surface creates air drag.

This illustration depicts the landing of a 40-metric-ton payload. (A metric ton is 1,000 kilograms of mass, or 2,200 pounds of weight on Earth.) The scenario is based on research by graduate students at the Georgia Institute of Technology under the direction of aerospace engineering professor Robert Braun.

Astronomy: Roen Kelly



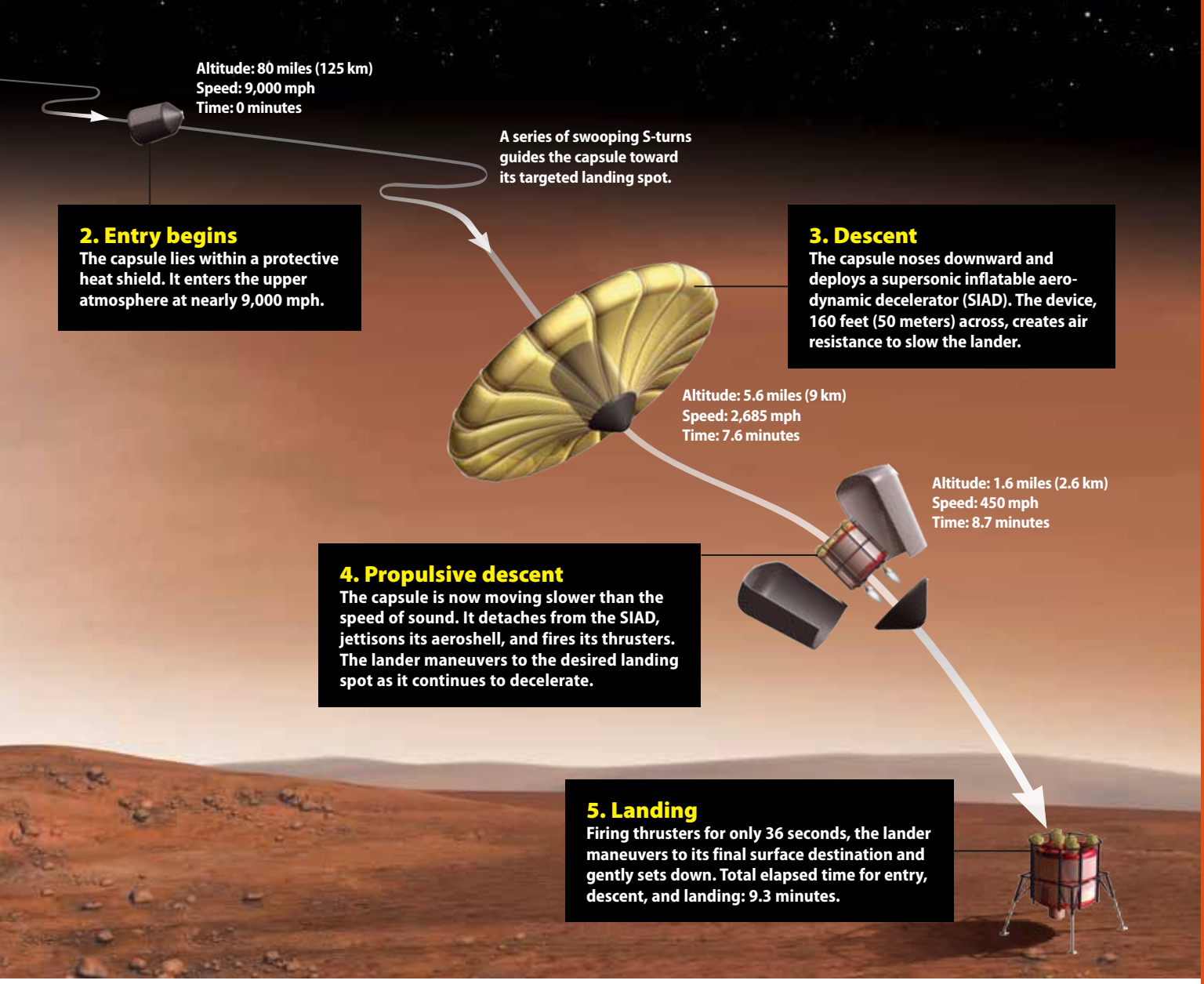
1. Aerocapture

At arrival, a spacecraft from Earth enters Mars orbit by decelerating through its upper atmosphere — a strategy called aerocapture. This maneuver brings the ship into a circular orbit at an altitude of about 250 miles (400 kilometers).

Mars Direct diverged radically from the previous all-up strategy. First, a cargo-only vehicle launches into space on a booster comparable to the Apollo-era Saturn 5. It carries an Earth Return Vehicle (ERV) that will eventually bring the astronauts home. The payload goes directly to Mars with no stopover in low Earth orbit for assembly or fueling. This is the "direct" part of Mars Direct.

The Earth Return Vehicle lands on Mars unfueled for the return flight. Instead, it carries in-situ resource utilization (ISRU) hardware. This includes an automated chemical processing plant, a nuclear electric generator, and liquid hydrogen "feedstock" (raw material to kick off the manufacturing process). The ISRU plant then combines the feedstock with carbon dioxide from the martian atmosphere to produce methane and oxygen for rocket fuel.

The crew lands, lives, and works in multilevel habitat landers. In an early Mars mission design, NASA would send one of the habitat landers on a robotic cargo flight. The crew would follow in a later launch, landing in the second habitat near the one already on Mars.


Altitude: 80 miles (125 km)
Speed: 9,000 mph
Time: 0 minutes
A series of swooping S-turns guides the capsule toward its targeted landing spot.
2. Entry begins
The capsule lies within a protective heat shield. It enters the upper atmosphere at nearly 9,000 mph.
3. Descent
The capsule noses downward and deploys a supersonic inflatable aerodynamic decelerator (SIAD). The device, 160 feet (50 meters) across, creates air resistance to slow the lander.
Altitude: 5.6 miles (9 km)
Speed: 2,685 mph
Time: 7.6 minutes
Altitude: 1.6 miles (2.6 km)
Speed: 450 mph
Time: 8.7 minutes
4. Propulsive descent
The capsule is now moving slower than the speed of sound. It detaches from the SIAD, jettisons its aeroshell, and fires its thrusters. The lander maneuvers to the desired landing spot as it continues to decelerate.
5. Landing
Firing thrusters for only 36 seconds, the lander maneuvers to its final surface destination and gently sets down. Total elapsed time for entry, descent, and landing: 9.3 minutes.

At the next favorable Earth-Mars alignment for a launch — 26 months after the cargo flight — the crew will depart Earth. But they will leave only after confirming the ISRU hardware has fueled the return ship. The crew ship is the equivalent of a small cottage with rocket propulsion. It carries a methane-burning rover, a crew of four, and everything they will need to live for 3 years.

The trajectory Mars Direct uses for the outbound and return flights minimizes the propellant required, but at the cost of an extended stay on the planet. After the 6-month cruise to Mars, the astronauts must remain there for about 600 days until Earth swings around to an orbital position that requires the least amount of fuel to reach home.

As the crew ship departs for Mars, a cargo flight blasts off to deliver a second Earth Return Vehicle into Mars orbit. This provides a safety margin: If the ERV sent earlier fails, the astronauts can still get home using the second one. And if the crew ends up not using the backup ERV, it will be waiting when the next crew arrives from Earth to explore Mars.

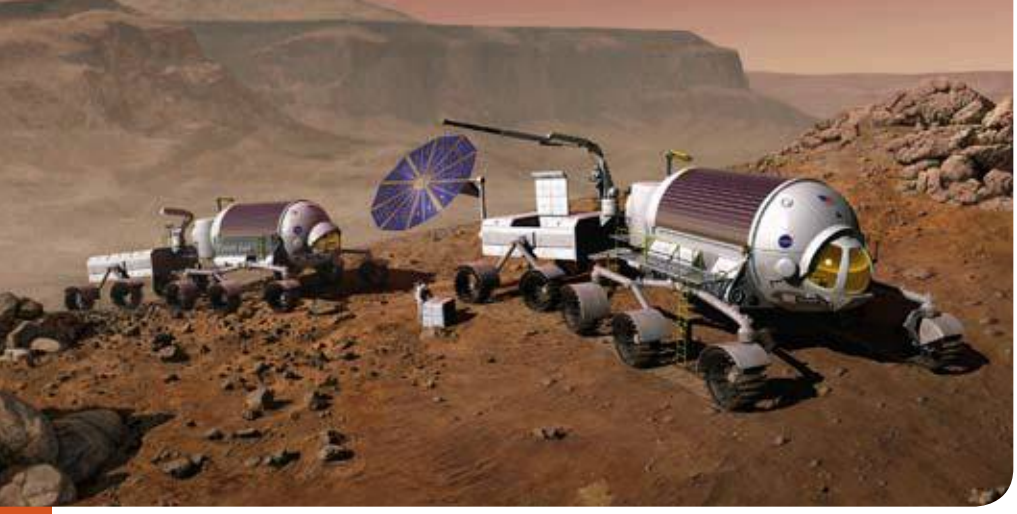
With every mission, the number of crew habitats and other equipment left on the surface increases. This provides the basis for a permanent human presence and perhaps colonization.

The price tag for Mars Direct was a key selling point. Zubrin's original estimate claimed it would take $20 to $30 billion and 10 years to develop the hardware plus $1 to $2 billion for subsequent piloted flights to the growing Mars outpost. Today, he says, it would cost in the neighborhood of $30 to $40 billion and $2 to $3 billion per additional visit.

NASA responds to Mars Direct

NASA followed Zubrin's lead with its Design Reference Mission (DRM), drawn up in the 1990s by scientists and engineers at Johnson Space Center. The DRM, like Mars Direct, is not a detailed set of spacecraft designs and procedures. NASA bills it as a general framework for developing, comparing, and improving architectures for a future Mars mission.

The DRM adopts Mars Direct's split-mission strategy and the "live off the land" philosophy that uses ISRU technology to manufacture propellent. An important difference, however, is that NASA's plan separates the return trip into two legs. The crew would blast off from the martian surface in a Mars Ascent Vehicle (MAV) and then transfer to a waiting interplanetary vehicle placed in orbit by a previous cargo flight.



The surface mission would last about 600 days. This provides ample time for exploration in far-ranging pressurized rovers. Astronauts will collect geological samples, study the atmosphere and weather, and maintain a stable of robotic helpmates. NASA artwork by Pat Rawlings/SAIC

In a 1998 update to the DRM, NASA planners abandoned the direct-to-Mars launch approach, opting for a strategy sometimes called Mars Semi-Direct. Doing so would eliminate the need to develop an expensive new launcher that could send NASA's heavy 200-ton-plus payloads hurtling to Mars. An 80-ton launcher would lift payload and propulsion stages into low Earth orbit, where they would dock and leave for Mars. This would require a minimum of six launches to get the first crew on Mars.

The NASA mission to Mars involves more and heavier hardware than Mars Direct, but it takes essentially the same approach. And like Mars Direct, the DRM helps make Mars exploration look a lot more feasible. NASA offered no official cost estimate for the DRM, but most likely it would be less than the $500 billion Bush initiative.

Landing on Mars

Mars Direct and the NASA reference mission are rough outlines. Many devilish details remain to be worked out. One of the most crucial ones is how to land heavy payloads in one piece. Aerospace engineers call the process EDL, or "entry, descent, and landing."

Right now, NASA does not officially fund research on human spaceflight to Mars. But scientists and engineers within and outside the agency continue to explore the challenge of martian EDL. It's a terrific test case for their students, and it may have applications for coming robotic missions to the Red Planet. The basic challenge of EDL is to slow down from hypersonic speed to a standstill in less than 10 minutes. Failing in this task could end with the payload at the bottom of a new crater on the martian surface.

"You have very high energy in orbit that you have to reduce to a tiny fraction." — Robert Manning

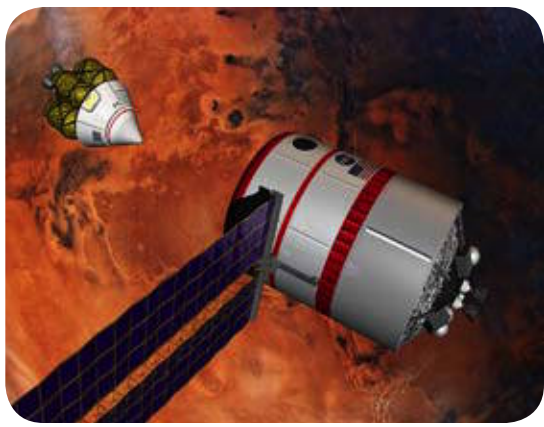
Most of the hard work occurs in the middle stage of the process, descent. "You have very high energy in orbit that you have to reduce to a tiny fraction of that — less than 1 percent — before you are even close to being able to choose how you touch the ground," says Robert Manning, chief engineer for the Mars Exploration Program at NASA's Jet Propulsion Laboratory (JPL) in Pasadena, California.

The touchdown of the Mars Phoenix Lander in May 2008 displayed the current state of the art for Mars landings. The craft's so-called "7 minutes of terror" started at the top of the martian atmosphere, about 80 miles (125 kilometers) above the surface. Phoenix entered from space at about 12,500 mph (20,000 km/h). Air resistance against its heat shield slowed the craft to about 900 mph (1,400 km/h). Then a parachute took the speed down to 250 mph (400 km/h). After a brief freefall, the craft fired thrusters at 3,200 feet (975 meters) and touched down — all in about 7 minutes.

Current EDL technology will reach its limit in 2011 with the planned landing of the Mars Science Laboratory (MSL). Its mass on the ground will be 1,984 pounds (900 kilograms). Conventional combinations of heat shields, parachutes, and thrusters are not up to the task of landing anything heavier than the MSL rover.

But Mars Direct and the NASA DRM envision payloads ranging from 30 to 60 metric tons. (A metric ton is 1,000 kilograms of mass, or about 2,200 pounds of weight on Earth.) With current EDL technology, we can't land a Cooper Mini on Mars — curb weight with manual transmission 2,524 pounds (1,145 kg) — much less a capsule with astronauts.

Manning and other EDL experts say a human landing will take new technolo-



> At the end of their visit, astronauts will leave in a Mars Ascent Vehicle and rendezvous with a spacecraft waiting in orbit to take them home.

>> A fully fueled return ship (far right) has waited in orbit for its precious cargo since being launched on a robotic cargo flight. Return trips from Mars could take 130 to 180 days, depending on the orbital geometry between Mars and Earth at departure time.

gies. Mars Direct and the Design Reference Mission both rely on parachutes for the descent. But the Red Planet's thin atmosphere means parachutes would need to be extremely large and able to deploy quickly at supersonic speeds without tangling or shredding. "You would need a parachute about a football field across," Manning says. "It would easily, when flattened out, be a nice canopy for the Rose Bowl."

Apollo-style landings entirely on thrusters are problematic, too. Decelerating from Mars orbit and landing using rockets would require a huge amount of propellent. Also, firing rockets in the martian atmosphere at hypersonic speed can create aerodynamic drag and instability that are hard to predict.

EDL experts at NASA and in the aerospace research community have brainstormed new options for the descent stage of a human landing on Mars. A leading contender is called the supersonic inflatable aerodynamic decelerator, or SIAD. Imagine a giant airbag in the shape of a badminton shuttlecock, and you get the general idea.

Aerospace engineer Robert Braun and his students at the Georgia Institute of Technology in Atlanta have worked out scenarios for landing heavy payloads with SIAD technology. They have developed detailed plans for how to land 20 metric tons of cargo mass — about 8.3 tons of weight in martian gravity — with an inflatable decelerator and thrusters.

The decelerators are still pretty big — up to 160 feet (50m) across — but the basic engineering is plausible. The inflatable slows the craft to about 450 mph (720 km/h), a speed at which it's possible to use rocket thrusters to maneuver the payload to the final landing site and decelerate to a soft landing.

The landed payload masses cited in the original NASA DRM were as much as 65 metric tons. Braun remains skeptical that such a landing is possible with any method he can currently imagine. "To land 65 metric tons — 100 times what we have accomplished with robotic landers — is a very large stretch," he says.

Braun would reduce each payload. "You'd be better off landing payloads of 15 metric tons," he says. That would reduce the size of the SIAD and make other EDL options more feasible.

After nearly 1,000 days away, Mars explorers return to Earth the same way astronauts have for half a century — in a cramped capsule. In this artist's rendering, the 5.5-ton capsule rides a steerable parafoil to a relatively soft landing on the ground. After the grueling, risky Mars mission, the crew won't mind a few bumps.

Insert miracle here

The challenge of landing heavy payloads on the martian surface is just one of the multiple leaps in technology required to carry out Mars Direct and the NASA reference mission. "There are a few 'miracle occurs' steps that we have to invent," Manning concedes.

Quickly inflating an SIAD — nearly the wingspan of a Boeing 747 — at several thousand miles per hour is among the major "insert miracle here" steps that stand in the way of getting to Mars. But don't despair, Manning says: "It's not impossible; it's just a challenge. Put this on your list of things to do, America."

On the extreme of Mars mission skepticism sits Donald Rapp, a retired JPL engineer who has performed detailed analyses of human spaceflight to Mars. In his 2007 book, *Human Missions to Mars*, Rapp dissects the underlying assumptions of the NASA Design Reference Mission on a cellular level.

Rapp credits the important role of Mars advocates like Zubrin. But he criticizes enthusiasm that may exceed reality. "They're visionaries," Rapp says. "People like Zubrin can look across the desert and see the greenery of the orchids beyond. But you still have to get across the desert, and they tend to underestimate grossly what it takes to do that."

Rapp says $10 billion a year for up to 30 years might get us to Mars. Factoring in the delay of NASA's plan to return to the Moon and all the unsolved challenges, he says it could take NASA until 2080 to get boots on the martian surface.

Zubrin has heard all this before. But he remains immune to naysayers and unrepentant in his belief in the importance of going to Mars. For him, the dream dates to the Kennedy-era rhetoric that inspired him to join the aerospace industry in the first place. Cue sound byte: We go to Mars not because it's easy, but because it is hard.

"Relative to our technology today, a mission to Mars is much less challenging than a mission to the Moon was in 1961," Zubrin says. "For us to throw up our hands at these problems and say we just can't do it is really saying we've become less of a people than we used to be."

Learn more about human spaceflight to Mars at www.Astronomy.com/toc.

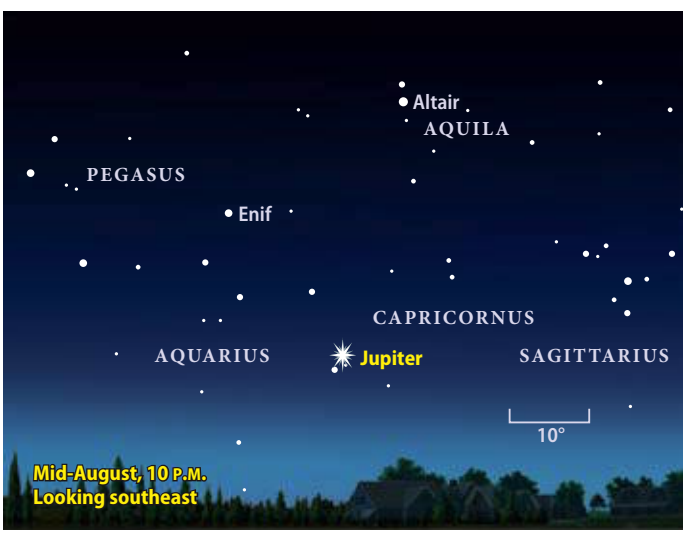
The Sky this Month

Martin Ratcliffe and Alister Ling describe the solar system's changing landscape as it appears in Earth's sky.

August 09

Jupiter reaches its peak

Giant Jupiter dominates the late-summer sky, reaching opposition August 14 and remaining visible all night. The best views through a telescope will come when it lies high in the south around midnight. NASA/JPL/SSI



Jupiter shines brilliantly at magnitude –2.9 when it peaks in mid-August. It hasn't shone this brightly since October 1999. *Astronomy*: Roen Kelly

You can retrace Galileo's footsteps this month by observing Jupiter and its four bright moons. Jupiter reaches opposition and peak visibility in August, and it remains on display all night. Its moons show up through any telescope.

During evening twilight, you can catch a brief glimpse of Mercury and a last look at Saturn. (The ringed planet disappears in the Sun's glare at month's end.) Binoculars will help you spot Uranus and Neptune — both planets unknown in Galileo's time. For those who prefer viewing before dawn, Mars and Venus make nice appearances.

You'll want to start looking for **Mercury** about 30 minutes after sunset, when the innermost planet lies low in the west. On August 2, you might think you're seeing double. Mercury appears 0.6° above Regulus, Leo the Lion's brightest star. Mercury shines at magnitude –0.4, some 5 times brighter than Regulus. The star will be a challenge to see because of its low altitude, and it likely will twinkle in and out of visibility.

Mercury's motion relative to the stars carries it across Leo and toward Saturn during August. By the 16th, the gap between the two planets shrinks to 3°. Mercury will be easier to spot because it glows at magnitude 0.1, a full magnitude brighter than Saturn. Look for the ringed planet about half a binocular field above Mercury. A week later, on August 22, the pair appear side by side, with Saturn to the right of its companion and a 8° gap between them. A crescent Moon stands 9° to Mercury's left, creating a lovely evening lineup.

Two nights later, Mercury lies 27° east of the Sun — its greatest elongation for this evening apparition. A half hour after sunset, the planet stands just 4° above the horizon. That same evening, the waxing crescent Moon lies alongside Spica, Virgo's brightest star.

Those with telescopes can grab their final evening views

— *Continued on page 41*

36 Jupiter at its best
41 Meteor watch
41 Rising Moon
42 When to view the planets
42 Jupiter's moons plus one
42 Comet search
43 Locating asteroids
43 Jupiter points to Neptune

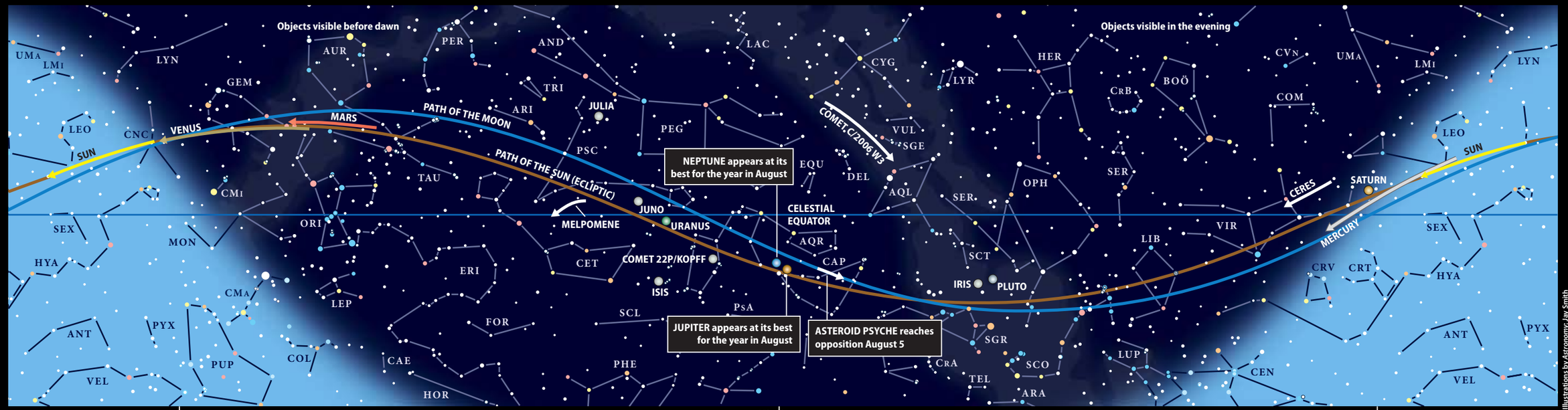
Visible to the naked eye
Visible with binoculars
Visible with a telescope

Planets in August 09

This map unfolds the entire night sky from sunset (at right) until sunrise (at left).
Arrows and colored dots show motions and locations of solar system objects during the month.

Astronomy magazine

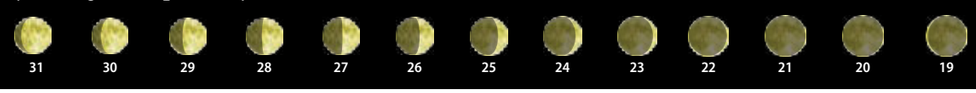
Path of the planets



Illustrations by *Astronomy*: Jay Smith

MOON PHASES

Dawn — Midnight — Early evening

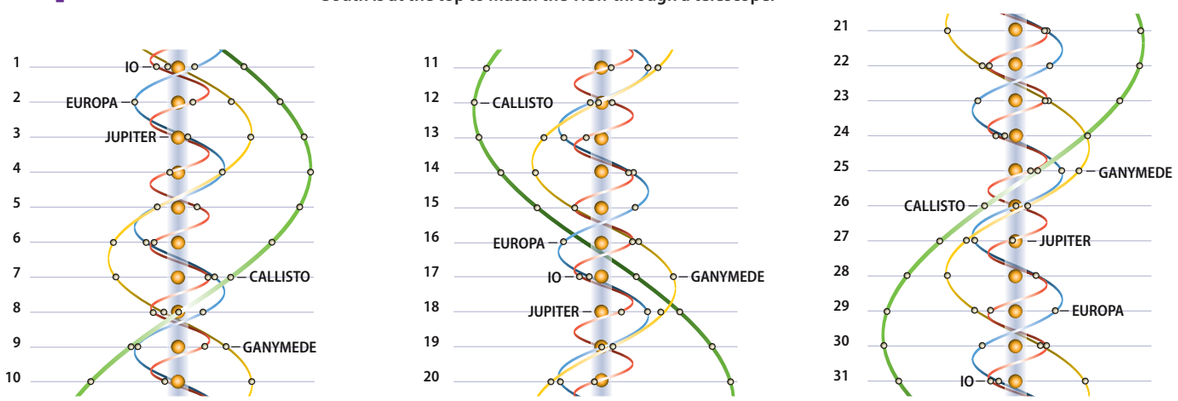


To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.
Note: Moons vary in size due to distance from Earth and are shown at 0h Universal Time.

PLANETS	MERCURY	VENUS	MARS	CERES	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
Date	August 15	August 15	August 15	August 15	August 15	August 1	August 15	August 15	August 15
Magnitude	0.0	–4.0	1.0	8.9	–2.9	1.1	5.8	7.8	14.0
Angular size	6.3"	13.6"	5.5"	0.4"	48.9"	16.3"	3.7"	2.4"	0.1"
Illumination	66%	78%	90%	98%	100%	100%	100%	100%	100%
Distance (AU) from Earth	1.060	1.225	1.696	3.257	4.028	10.178	19.246	29.017	31.053
Distance (AU) from Sun	0.461	0.723	1.465	2.606	5.040	9.429	20.098	30.028	31.691
Right ascension (2000.0)	11h13.9m	7h09.3m	5h29.2m	12h28.1m	21h38.5m	11h23.5m	23h45.6m	21h49.7m	18h03.0m
Declination (2000.0)	4°19'	21°35'	23°10'	5°01'	–15°14'	6°06'	–2°25'	–13°35'	–17°50'

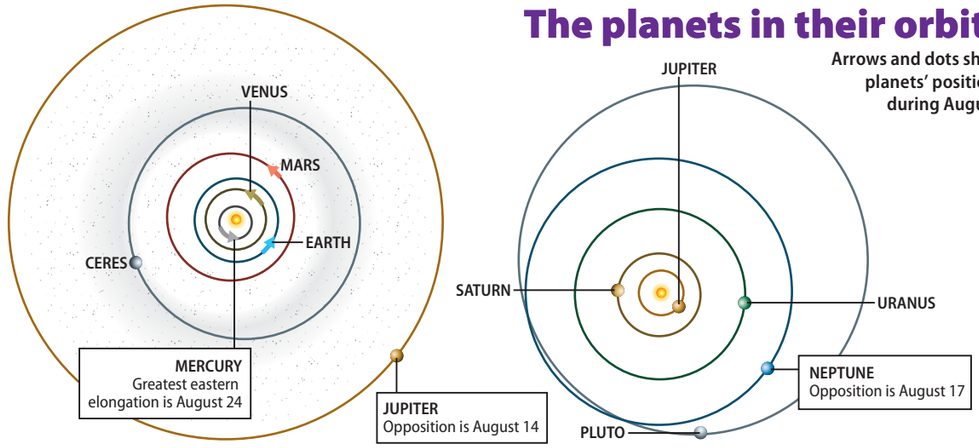
Jupiter's moons

Dots display positions of Galilean satellites at 11 P.M. EDT on the date shown.
South is at the top to match the view through a telescope.



The planets in their orbits

Arrows and dots show planets' positions during August.



StarDome

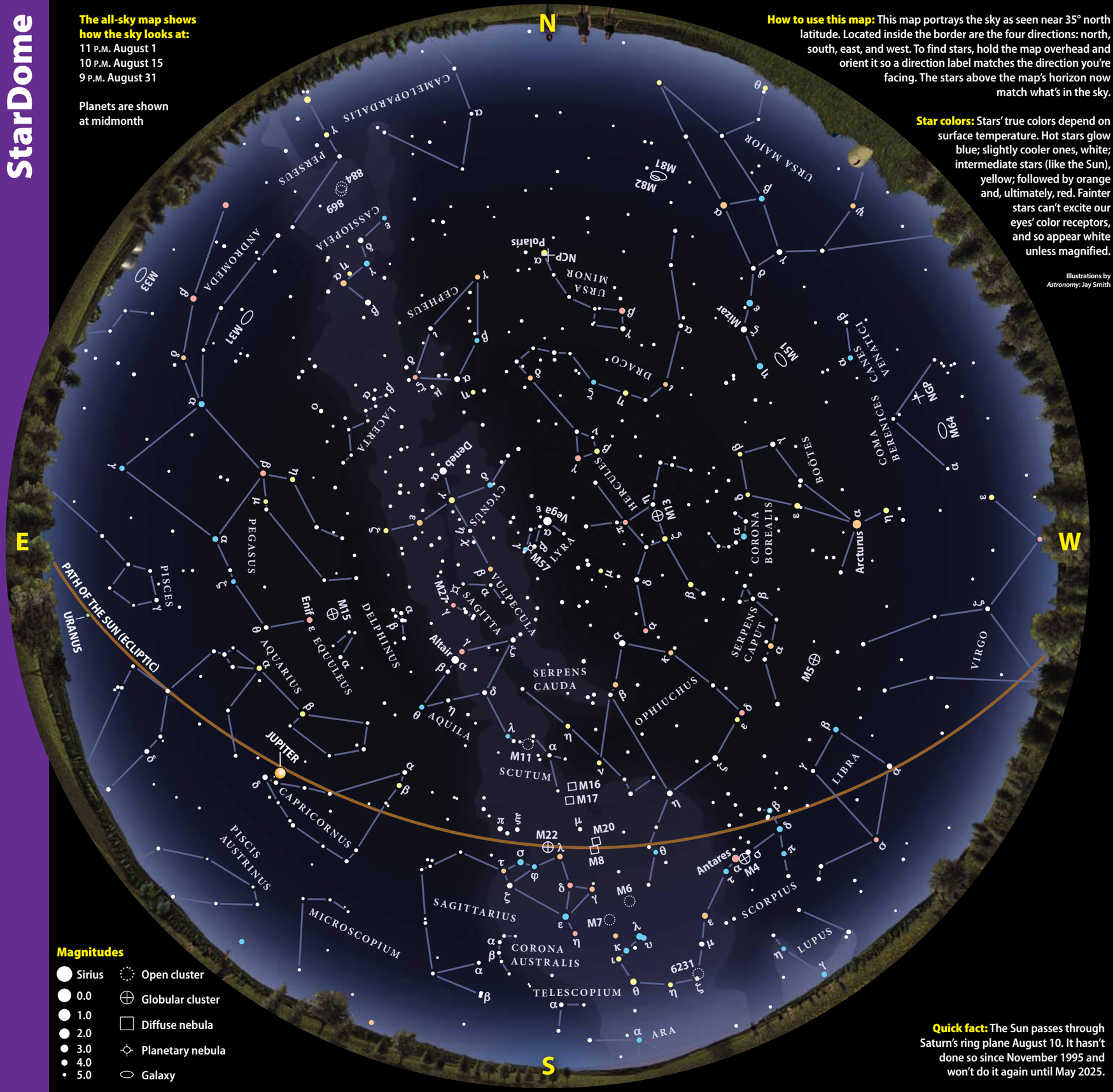
The all-sky map shows how the sky looks at:
11 P.M. August 1
10 P.M. August 15
9 P.M. August 31

Planets are shown at midmonth

How to use this map: This map portrays the sky as seen near 35° north latitude. Located inside the border are the four directions: north, south, east, and west. To find stars, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

Star colors: Stars' true colors depend on surface temperature. Hot stars glow blue; slightly cooler ones, white; intermediate stars (like the Sun), yellow; followed by orange and, ultimately, red. Fainter stars can't excite our eyes' color receptors, and so appear white unless magnified.

Illustrations by *Astronomy*: Jay Smith



Magnitudes

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0
- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

Quick fact: The Sun passes through Saturn's ring plane August 10. It hasn't done so since November 1995 and won't do it again until May 2025.

August 09

Note: Moon phases in the calendar vary in size due to the distance from Earth and are shown at 0h Universal Time.

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

Calendar of events

2 Mercury passes 0.6° north of Regulus, 3 P.M. EDT

3 The Moon is at apogee (252,294 miles from Earth), 8:42 P.M. EDT

5 Full Moon occurs at 8:55 P.M. EDT; penumbral lunar eclipse

Asteroid Psyche is at opposition, 9 P.M. EDT

6 The Moon passes 3° north of Jupiter, 6 P.M. EDT

The Moon passes 3° north of Neptune, 10 P.M. EDT

9 The Moon passes 6° north of Uranus, 1 P.M. EDT

10 The Sun passes through Saturn's ring plane, 9 P.M. EDT

12 Perseid meteor shower peaks

13 Last Quarter Moon occurs at 2:55 P.M. EDT

Special observing date

14 Jupiter appears larger (48.9" across) and shines brighter (magnitude –2.9) than at any time since October 1999.

14 Jupiter is at opposition, 2 P.M. EDT

15 Asteroid Juno is stationary, 2 P.M. EDT

15 The Moon passes 3° north of Mars, 11 P.M. EDT

17 Neptune is at opposition, 5 P.M. EDT

The Moon passes 1.7° north of Venus, 5 P.M. EDT

18 The Moon passes 0.4° north of the asteroid Vesta, 3 A.M. EDT

Mercury passes 3° south of Saturn, 5 P.M. EDT

19 The Moon is at perigee (223,469 miles from Earth), 12:58 A.M. EDT

20 N Moon occurs at 6:02 A.M. EDT

21 Venus passes 7° south of Pollux, midnight EDT

22 The Moon passes 7° south of Saturn, 2 A.M. EDT

The Moon passes 3° south of Mercury, 8 A.M. EDT

24 Mercury is at greatest eastern elongation (27°), noon EDT

27 F Quarter Moon occurs at 7:42 A.M. EDT

The Moon passes 0.6° north of Antares, 6 P.M. EDT

31 The Moon is at apogee (251,823 miles from Earth), 7:02 A.M. EDT

See tonight's sky in Astronomy.com's STARDOME

Astronomy magazine

— *Continued from page 36*

of **Saturn** in early August. The rings tilt just 2° to our line of sight and will be hard to see through the thick air near the horizon. The rings will disappear by August 10, when they tip edge-on to the Sun and no longer reflect light back toward Earth. Saturn itself becomes lost in the Sun's glow by month's end. It will be in conjunction with the Sun in September and return to the morning sky — with narrow but lit rings — in October.

By the time Mercury and Saturn set, **Jupiter** appears above the southeastern horizon. If you point a telescope toward the giant planet in the early evening, however, you likely will be disappointed — atmospheric turbulence does a thorough job of smearing detail. It's better to wait until late in the evening after Jupiter climbs higher into the southern sky.

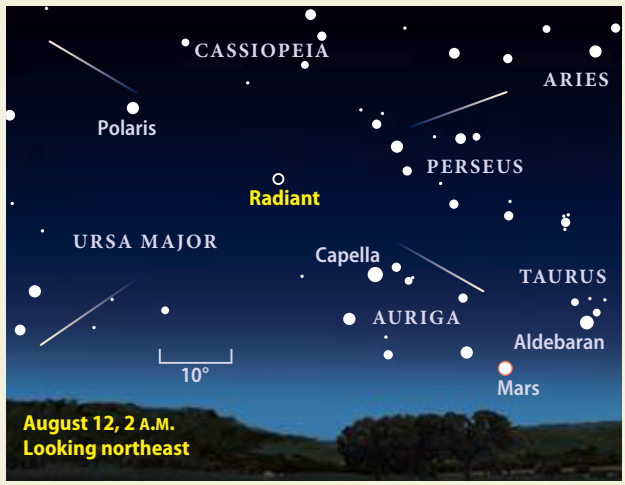
Jupiter reaches opposition August 14. It then lies opposite the Sun in our sky and shines brightest (at magnitude –2.9). It reaches its highest point in the south at midnight local time (1 A.M. daylight time). The planet then lies at least one-third of the way to the zenith for observers in most of the United States and southern Canada.

At opposition, Jupiter lies closest to Earth and so appears at its biggest for the year — an impressive 49" across. The large size makes this a great time to track atmospheric features across Jupiter's disk. You can see them move noticeably within just 10 to 15 minutes as Jupiter's fast rotation carries them around.

Imagine Galileo's surprise in 1610 when he found four moons following Jupiter night after night. Of course, everyone now recognizes the Sun's powerful influence at the center of our solar system, and it's hard for us to imagine just how radical Galileo's suggestion was that Earth was not

Martin Ratcliffe *provides professional planetarium development for Sky-Skan Inc. in Nashua, New Hampshire. Meteorologist* **Alister Ling** *works for Environment Canada in Edmonton, Alberta.*

Meteor watch



The Perseid meteor shower peaks before dawn August 12. A Last Quarter Moon will interfere somewhat with the view, but the brighter Perseids still will put on a fine show. *Astronomy*: Roen Kelly

Returning to a Hero's welcome

August usually ranks among the best months for observing meteors, but this year is tempered somewhat. Light from a Last Quarter Moon interferes with the normally prolific Perseid shower.

According to the International Meteor Organization, the Perseids may exhibit a double peak this year. The traditional peak should occur between 1:30 P.M. and 4 P.M. EDT August 12. Detailed models of the trail left in 1610 by the Perseids' parent comet, 109P/Swift-Tuttle, show that a second peak may come when Earth arrives near this orbit around 5 A.M. EDT August 12.

The Kappa Cygnid shower peaks August 17. The term "peak" may overstate the case, however, because this shower produces only 3 meteors per hour. Nonetheless, Kappa Cygnids move relatively slowly. Their graceful paths are a sight to behold.

Rising Moon

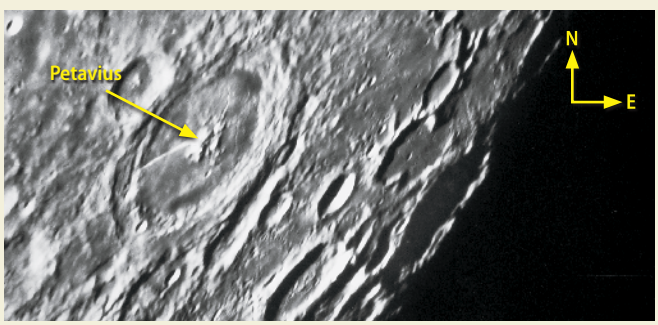
Petavius puts on a pretty show

When the Sun rises or sets on Petavius, this large crater is one of the most eye-catching features in sight. The 110-mile-wide crater features complex central peaks, a conspicuous radial trench, and a valley that runs tangent to its eastern rim. Yet in the full light of high noon, it hides surprisingly well.

To find Petavius, start at the southern end of Mare Fecunditatis. This mare is the largest lava lake in the lunar southeast. The bright splat on its southeastern shore is the relatively young crater Petavius B. The small dark patch just to the south lies inside Petavius.

The crater's normally striking features hide in plain sight under the high Sun as August opens. But by the evening of August 6, just 1 day before the Sun sets over the region, the eastern rim appears bright and the central peaks stand out. Stealing the show, however, is a dramatic white ray that runs from these peaks to the crater's southwestern edge. This ray is one side of a rille catching the setting Sun's rays. The crack likely formed when underground lava bulged upward in the distant past.

Vallis Palitzsch — the valley that runs just outside Petavius' eastern flank — lies in complete darkness the night of August 7. Return to the crater every 15 minutes to view the impressive shadows cast by the central mountains as they slowly reach out toward the terminator when the Sun dips below the horizon.



The lunar crater Petavius sports a complex chain of central peaks and a deeply carved rille. This view mimics what observers will see the evening of August 6, just before the Sun sets on the feature. *Consolidated Lunar Atlas*/UA/LPL

Your next view of this area comes August 22. Petavius' lunar day begins after our earthly sunset. The interior rille now appears dark and obvious. After just one more spin of Earth, it will blend into the surroundings as the higher Sun erases the evanescent shadows.

When to view **the planets**

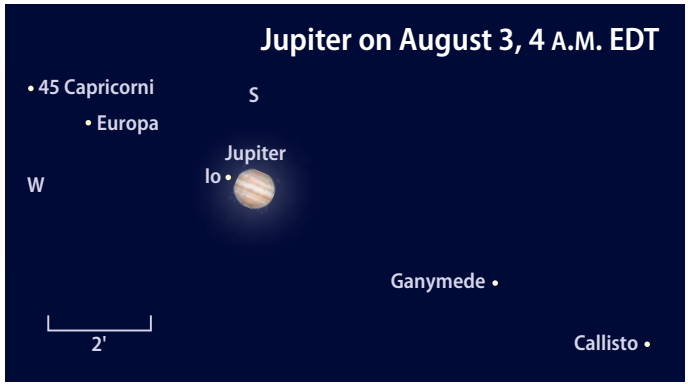
EVENING	MIDNIGHT	MORNING
Mercury (west)	Jupiter (south)	Venus (east)
Jupiter (southeast)	Uranus (southeast)	Mars (east)
Saturn (west)		Jupiter (southwest)
		Uranus (southwest)

the center of all motion. His observations of Jupiter and its family of four moons helped usher in a fundamental change: Who decided on perceived truth? Was it thoughtful philosophers or keen observers simply examining nature? The "seeing-is-believing" crowd eventually won the day. Working together, observers and theorists formed the fundamental basis for all of modern science.

Viewers in early August will be in for their own surprise. On the nights of August 2/3 and 4/5, Jupiter looks like it has five moons. The interloper is the 6th-magnitude star 45 Capricorni, which lines up with the four moons to make its identification even more difficult.

The star lies closest to Jupiter August 3/4, but so do Io and Europa, which complicates matters. Europa passes behind Jupiter before sunset on the 3rd and remains out of sight until 11:16 P.M. EDT. Io disappears behind Jupiter at 10:06 P.M. EDT and doesn't return to view until 12:39 A.M. EDT. So, for viewers in eastern North America, Jupiter appears to start the night with four moons, drops to three when Io gets blocked, returns to four when Europa reappears, and then reaches five after Io comes back.

Jupiter may look weird with five moons, but not that much stranger than with only one. Callisto will be the lone moon visible to the side of Jupiter for a period of time August 26/27. At 9:24 P.M. EDT, Ganymede starts to transit Jupiter's face. Nineteen minutes later, Europa follows suit. And 16 minutes after that (at 9:59 P.M. EDT), Io disappears behind the planet.



Jupiter's Galilean moons put on an ever-changing display as they orbit the planet. On the night of August 2/3, Jupiter appears to have five moons as the star 45 Capricorni passes by. *Astronomy*: Roen Kelly

Only Callisto stands clear of Jupiter until 12:35 A.M. EDT. That's when both Io and Europa reappear, Io east of Jupiter and Europa west. Ganymede returns at 1:02 A.M. EDT. You might spot Europa and Ganymede against Jupiter's cloud tops, but you'll have no trouble seeing their black shadows traversing the planet's disk. Europa's shadow transit starts at 10:21 P.M. EDT and runs to 1:12 A.M. EDT; Ganymede's begins at 10:41 P.M. EDT and ends at 2:20 A.M. EDT.

Jupiter conveniently points to **Neptune**. The two planets continue to move westward against the background stars of Capricornus. Because Jupiter travels faster, however, the gap between them grows. You can find Neptune 2° east of Jupiter August 1 and 5° away August 31.

Neptune reaches opposition and peak visibility August 17. It then lies 2.6°

Comet search

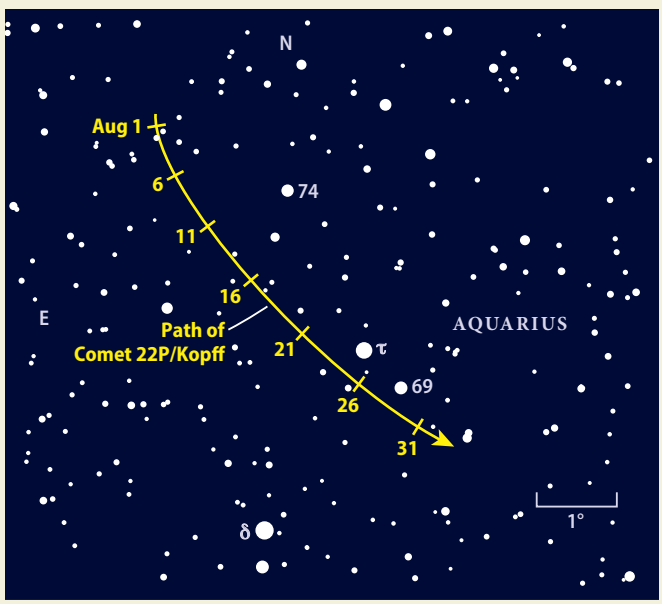
A snowball crosses a water expanse

Do you have a star party observing list? This summer, be sure to include Comet 22P/Kopff. The season's top comet crosses the southern sky late at night and will show up best from a dark site. As it ambles across Aquarius the Water-bearer east of Jupiter, this periodic visitor to the inner solar system should glow around 9th magnitude.

Comet 22P/Kopff is now on its 16th return since German astronomer August Kopff discovered it in 1906. During the past century, this comet has been pretty dependable. Each time it approaches closest to the Sun, it spews out a similar amount of gas and dust.

Although this year's return is pretty good for earthbound observers, not all are. The comet's 6.4-year orbital period means that every time we get a good view of it, the next one will be poor because Earth then will lie on the opposite side of the Sun from the comet. Interestingly, a close approach to Jupiter in 2026 will modify the comet's orbit to bring us a particularly nice apparition in 2028, when Kopff then should become a naked-eye object.

If you follow 22P/Kopff during the entire summer, you may notice that its apparent path on the sky creates a retrograde loop just like that of nearby Jupiter. When Earth orbits closer to the Sun than another object, the distant one appears to slow down and change direction as we overtake it on our inside track.



Comet 22P/Kopff should glow around 9th magnitude as it heads slowly westward against the background stars of Aquarius. *Astronomy*: Roen Kelly

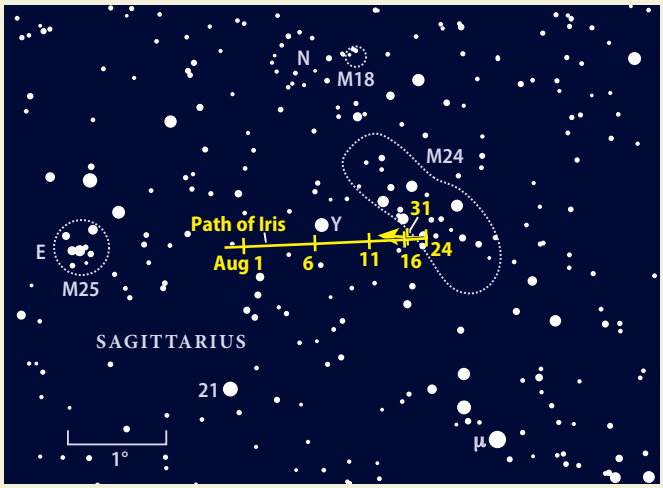
Minor planet Iris takes a steam bath

Large asteroids can be easy to spot when they stand out from the background star field. To do so, they either must be bright or located in a star-poor region. In summer, the asteroid belt crosses in front of our galaxy's heart, which guarantees oodles of background stars. But don't give up. The Milky Way also contains many dark nebulae — clouds of dust and gas that blot out background stars.

This month, a bright asteroid passes in front of a dark nebula. Check out minor planet 7 Iris next to the Small Sagittarius star cloud (M24) during your favorite star party in August's second half.

M24 appears stunning under a dark sky, whether you view it at low power in a small scope or at medium power in a big one. The dust clouds Barnard 92, 93, 304, and 307 appear like globs of black paint on M24's northern flank. It's a pity that Iris doesn't track in front of those, but it does pass across a dark nebula just to their southeast, which Barnard noted but did not number.

Glowing from reflected sunlight at magnitude 9.5, Iris skims less than 2' south of a 7th-magnitude star during August's final nights. It will pull away slowly to the east in early September.



Iris crosses star-rich Sagittarius this month, not far from the star cloud M24, but its visibility improves when it passes in front of a conveniently placed, but unnamed, dark nebula. *Astronomy*: Roen Kelly

north of 3rd-magnitude Delta (δ) Capricorni, the brightest star in Capricornus. In the same binocular field, you'll see 5th-magnitude Mu (μ) Cap. Neptune lies just 1 Moon-width west of this star August 1 and triple this distance by month's close, when it appears midway between Mu and 42 Cap. Glowing at magnitude 7.8, Neptune won't be simple to pick out through binoculars unless you mount them on a tripod.

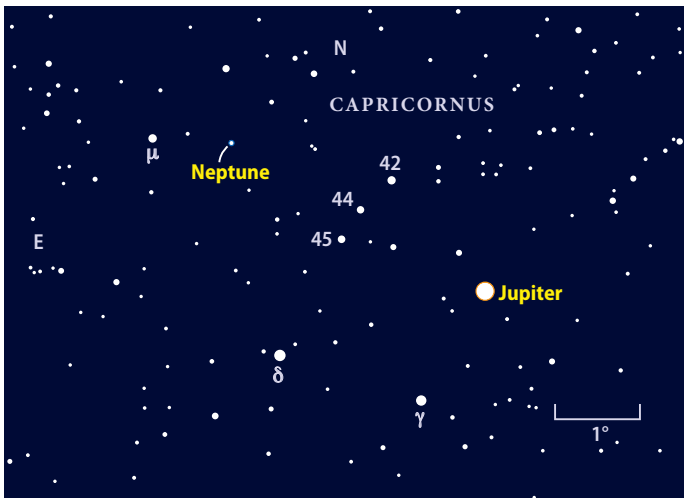
Some 171 years after Galileo's observations started to transform our view of the solar system, William Herschel discovered the object we now call **Uranus**. This distant world was the first major planet discovered with a telescope.

Uranus currently lies in Pisces the Fish, below that constellation's familiar Circlet asterism. This region pokes above the eastern horizon well before midnight. Unlike Neptune, Uranus proves easy to spy through hand-held binoculars. To do so, first center Lambda (λ) Piscium in the field. Next, move 4° south to find a pair of 6th-magnitude objects, which lie 1 Moon-width apart August 1. The upper object is Uranus, and the lower one is the star 20 Piscium. During August, the gap between the two increases to about 1°. By late August, you'll find Uranus at the western end of a line of three stars: 27, 24, and 20 Psc. All four objects shine at roughly the same brightness.

Mars spends most of August traveling eastward through Taurus the Bull, but it crosses into Gemini the Twins during the month's final week. On August 1, the Red Planet shines at magnitude 1.1 and rises around 2 A.M. local daylight time. It comes up about an hour earlier by the 31st.

As Mars passes between the Bull's horns August 15 and 16, a crescent Moon joins the scene. On the 29th, Mars slides just south of the open star cluster M35. Two days later, the planet stands 1° due north of the red giant star Eta (η) Geminorum. Mars remains tiny when viewed through a telescope, its disk reaching just 6" across. By December, it will appear twice as big.

About 2 hours after Mars rises and more than an hour



Neptune reaches opposition in mid-August, not far from Jupiter. The proximity of brilliant Jupiter makes it relatively easy to find 8th-magnitude Neptune through binoculars or a small telescope. *Astronomy*: Roen Kelly

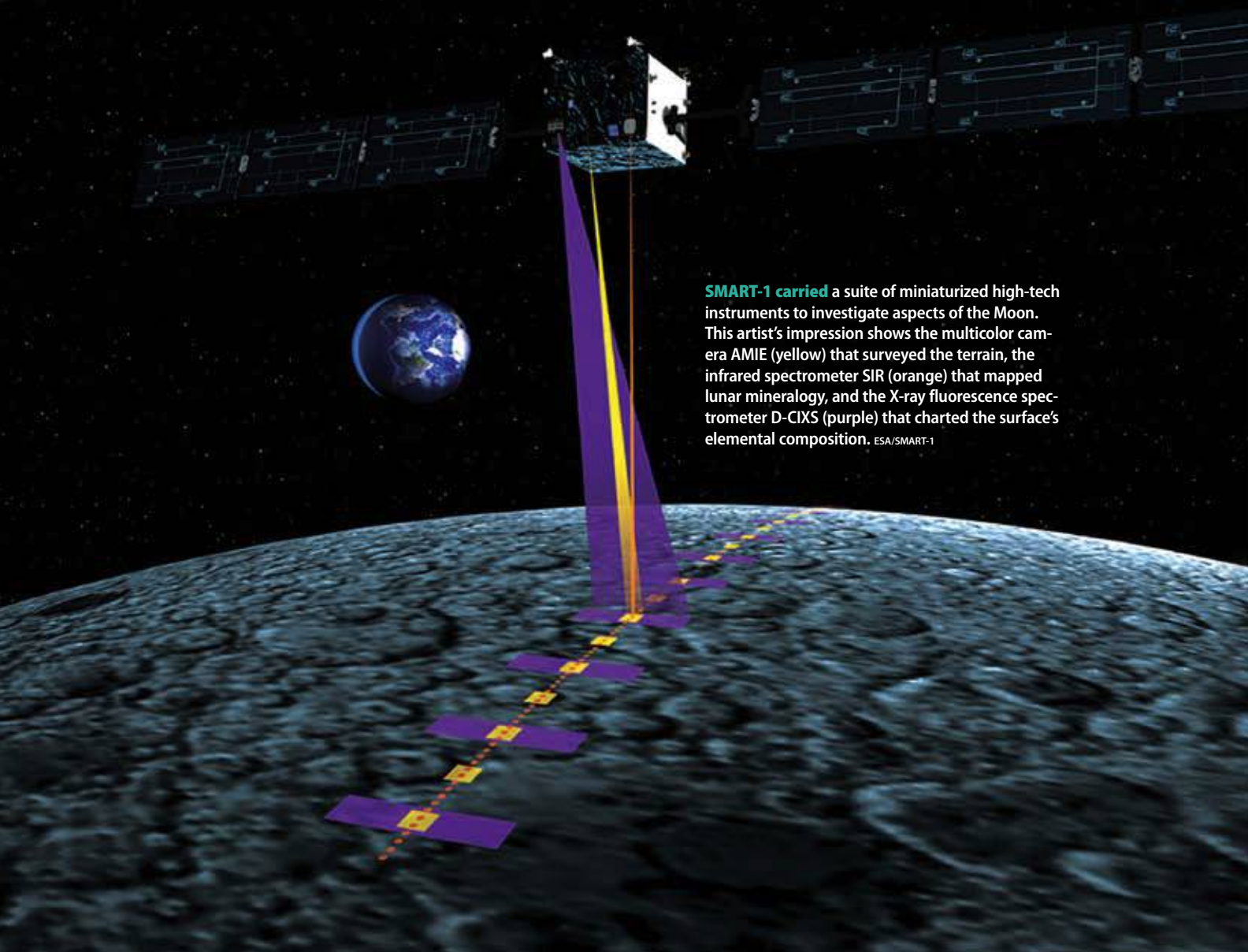
before twilight begins, **Venus** pokes above the northeastern horizon. The brilliant planet crosses the length of Gemini during August. It passes just south of Eta and Mu Geminorum August 4 and 5, respectively. On the 25th, Venus forms a long line with Castor and Pollux as it crosses into Cancer the Crab. On August's final morning, you can find the planet 2° west of the Beehive star cluster (M44).

Through a telescope, Venus shows a gibbous phase all month. Its lit part fattens from 74 percent to 83 percent during August. Over the same time span, Venus' apparent diameter shrinks from 15" to 13" as it moves significantly farther from Earth.

Viewing Venus in a dark sky is stunning — at magnitude –4.0, it beats everything in the night sky except the Moon. The Moon passes 7° above Venus August 17. The two swap places the following morning, with the Moon resting 7° below the planet.

What Europe's Moon mission **revealed**

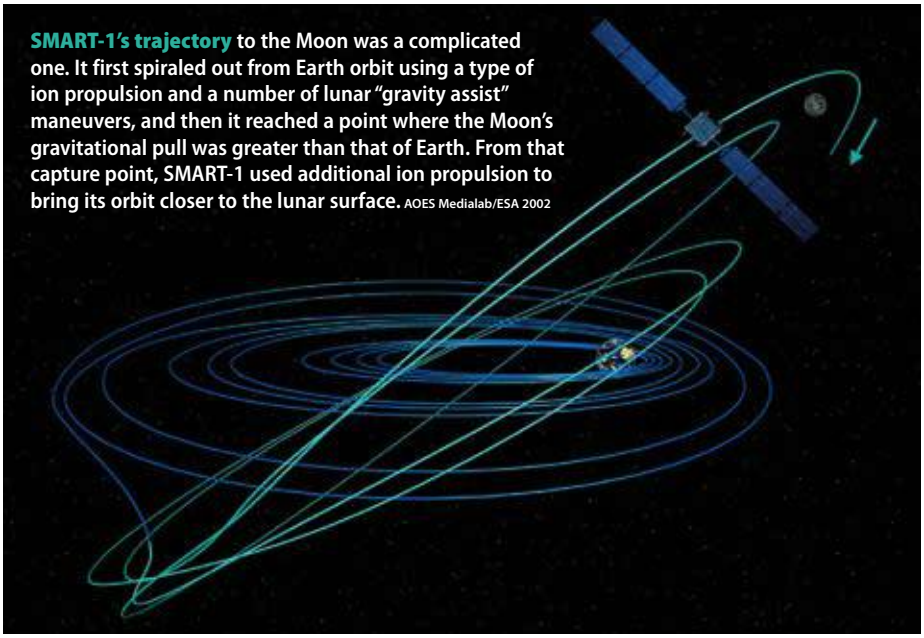
Lead Project Scientist **Bernard H. Foing** explains how SMART-1 served as a steppingstone for future solar system exploration.



SMART-1 carried a suite of miniaturized high-tech instruments to investigate aspects of the Moon. This artist's impression shows the multicolor camera AMIE (yellow) that surveyed the terrain, the infrared spectrometer SIR (orange) that mapped lunar mineralogy, and the X-ray fluorescence spectrometer D-CIXS (purple) that charted the surface's elemental composition. ESA/SMART-1

Six years ago the European Space Agency (ESA) sent its first probe to the Moon. This craft — the first project in the Small Missions for Advanced Research and Technology (SMART) program — explored our satellite while testing a new propulsion method and other technologies.

The SMART-1 probe launched September 27, 2003, aboard an Ariane 5 rocket. It was the first mission to use only solar power to escape Earth's orbit.



SMART-1's trajectory to the Moon was a complicated one. It first spiraled out from Earth orbit using a type of ion propulsion and a number of lunar "gravity assist" maneuvers, and then it reached a point where the Moon's gravitational pull was greater than that of Earth. From that capture point, SMART-1 used additional ion propulsion to bring its orbit closer to the lunar surface. AOES Medialab/ESA 2002

A "green" spacecraft

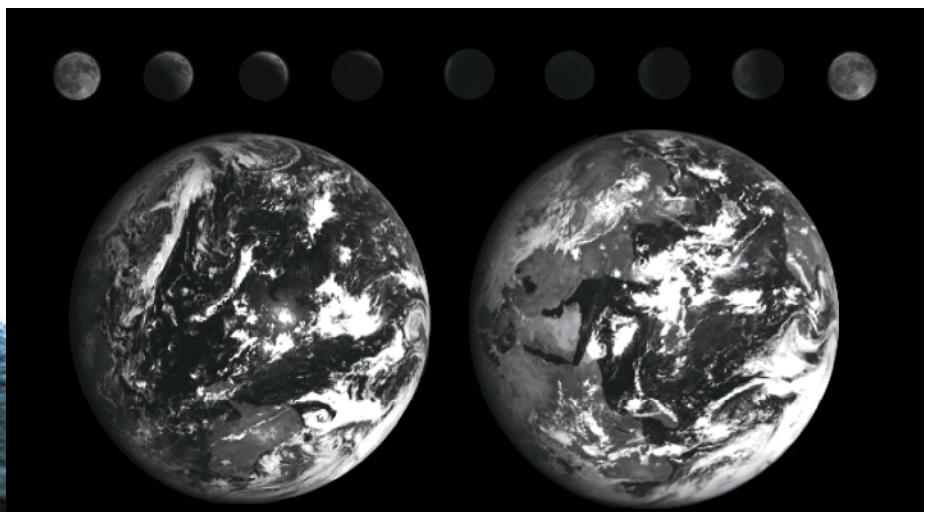
SMART-1 was the most fuel-efficient mission to the Moon (at 10,000 miles per gallon) and took 13 months to get there. The spacecraft used a type of thrust called "solar-electric propulsion." With the spacecraft's 46-foot (14 meters) solar panel wingspan, it caught sunlight and used the Sun's energy to generate electricity. The craft's propellant was xenon gas.

The solar-generated electricity charged the gas atoms, which turned them into ionized atoms, or "ions." The engine expelled the ions out of the back of the spacecraft at 5 miles per second (8 kilometers/s). This created a small and continuous thrust.

Because ion propulsion is about 10 times more efficient than conventional spacecraft engines, SMART-1 required less fuel and therefore weighed less. The craft's 805 pounds (365 kilograms) included just 180 pounds (82 kg) of xenon fuel and also packed numerous small science instruments.

After launch, SMART-1 entered an elliptical trajectory called a geostationary transfer orbit (GTO). The spacecraft then used only ion propulsion to spiral out of GTO until the Moon's gravitational pull captured it in November 2004. During the next 4 months, mission controllers used small gravitational shifts combined with the continuous propulsion thrust to help the spacecraft reach closer lunar orbit. On March 15, 2005, SMART-1 entered a lunar orbit — with closest approach of 250 miles (400 km) and farthest distance of 1,860 miles (3,000 km) — for a planned science period of 6 months. In February 2005, ESA approved a 1-year extension, which allowed us to do far more science.

Bernard H. Foing *is chief scientist of ESA's Research and Scientific Support Department and lead project scientist of SMART-1.*



SMART-1's multicolor camera AMIE snapped this Earth-Moon family portrait during the total lunar eclipse October 28, 2004. This image marked the first time that a spacecraft has photographed both Earth and the Moon during a lunar eclipse. The apparent relative size of Earth and the Moon in this picture is how SMART-1 saw them. The Moon sequence goes from left to right, where totality is in the middle of the sequence. The images are from 1h14m UT to 4h54m UT, and totality lasted about an hour from 2h23m UT to 3h45m UT. ESA/SMART-1/AMIE

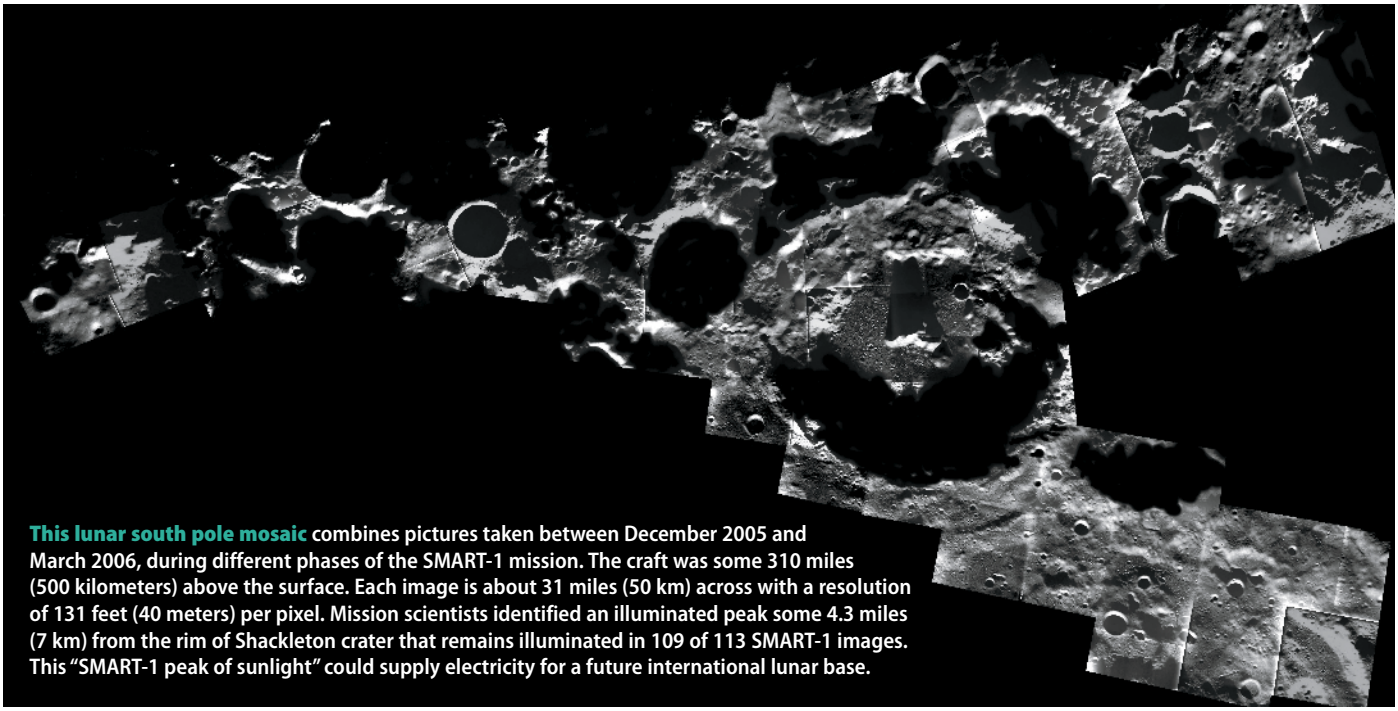
Mapping the Moon

SMART-1 studied the chemical composition of the Moon and geophysical processes (volcanism, tectonics, cratering, erosion, and deposition of ices and volatiles) to compare those characteristics with those on Earth. The mission also addressed the accretion processes that led to the formation of rocky planets, along with the origin and evolution of the Earth-Moon system.

The spacecraft also served as a test bed for various technologies, including miniaturized instruments. Its science payload amounted to only about 42 pounds (19 kg), and that included 7 experiments — these were small apparatuses!

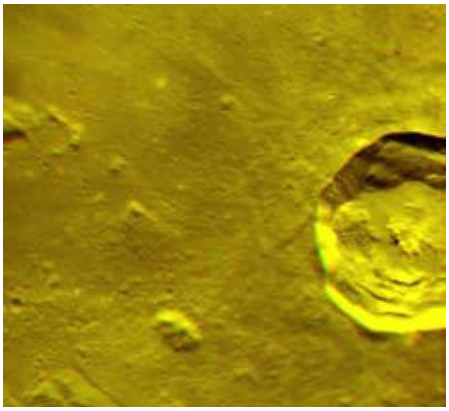
The centerpieces of SMART-1's instrument payload were three miniature cameras to observe different types of light. We observed visible light to map the Moon's terrain, infrared light to map the Moon's minerals, and X rays to identify chemical elements in the Moon's surface.

The Advanced Moon micro-Imager Experiment (AMIE) was the camera that observed in visible light. With a resolution



This lunar south pole mosaic combines pictures taken between December 2005 and March 2006, during different phases of the SMART-1 mission. The craft was some 310 miles (500 kilometers) above the surface. Each image is about 31 miles (50 km) across with a resolution of 131 feet (40 meters) per pixel. Mission scientists identified an illuminated peak some 4.3 miles (7 km) from the rim of Shackleton crater that remains illuminated in 109 of 113 SMART-1 images. This "SMART-1 peak of sunlight" could supply electricity for a future international lunar base.

ESA/SMART-1/AMIE team



Between Oceanus Procellarum and Mare Insularum lies Kepler, a young crater. This image is best viewed with 3-D red-and-green glasses (where red is on the left eye). ESA/SMART-1/AMIE

of 131 feet (40m) per pixel at 250 miles (closest approach), AMIE was the highest-resolution camera to map the Moon's terrain in color. (The previous record was a resolution of 656 feet [200m] per pixel — that's a 6-fold improvement.) Data from AMIE also provide geological context for the other imaging experiments.

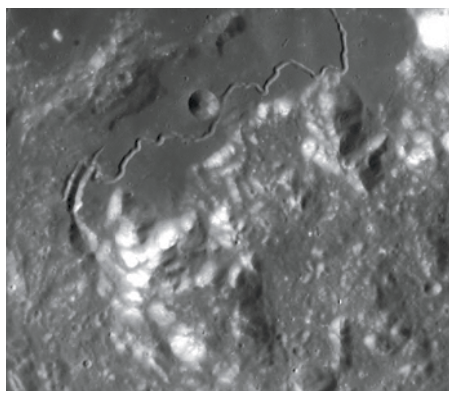
This micro camera included three color filters at 750 nanometers, 900nm, and 950nm, and a white-light filter. We used AMIE to map sites relevant to the study of impacts, such as the giant South Pole-Aitken Basin on the lunar farside. We also wanted to preview future sample return mission sites. We mapped the north and south poles by creating mosaics of high-resolution images to monitor how the Sun illuminates that part of the Moon. This helps us identify potential sites for future exploration.

The SMART-1 Infrared Spectrometer (SIR) surveyed the Moon's minerals in infrared light. When sunlight hits a particular mineral, that mineral will absorb certain characteristic colors, or wavelengths. An infrared spectrometer observes the infrared light and breaks it apart into a sort of rainbow, called a spectrum. By observing what wavelengths were missing from the spectrum (because the minerals absorbed them), we were able to determine mineral composition. By doing this study over a large portion of the Moon, we charted the mineral content of never-before mapped areas.

SIR carried out a mineralogical survey and studied the underlying layers of the lunar crust. The survey had high enough spatial resolution — it looked at details about 1,310 feet (400m) wide — to distinguish large impact craters' central peaks, walls, rims, and blankets of debris blasted outward by the impacts. We improved upon SIR for the SIR-2 instrument that launched October 22, 2008, aboard India's Chandrayaan-1 mission to the Moon.

When high-energy X rays hit the lunar surface, atoms absorb the energy, which excites the electrons. This emits an electron in addition to radiation at wavelengths specific to each element. This process is called X-ray fluorescence. Lunar material absorbs high-energy solar X rays and then emits lower-energy X rays.

Aboard SMART-1, we sent the first system to map X-ray fluorescence on the lunar surface. This system — called the Demonstration of a Compact Imaging X-ray Spectrometer (D-CIXS) — mapped the Moon's elemental composition. The amount of different elements can tell us about the Moon's origin and evolution. And a site rich in magnesium and titanium may be useful as a future landing site for manned missions. In particular, we wanted to measure the abundance of magnesium, aluminium, silicon, and iron



Lunar sinuous rilles are probably the most recognizable small volcanic features on the Moon. The rilles mark lava channels or collapsed lava tubes that formed during mare volcanism. SMART-1 snapped this photo of the Hadley Rille near the Apollo 15 landing site. The rille is about 75 miles (120 kilometers) long. ESA/SMART-1/AMIE

across the whole Moon, and especially in large impact basins.

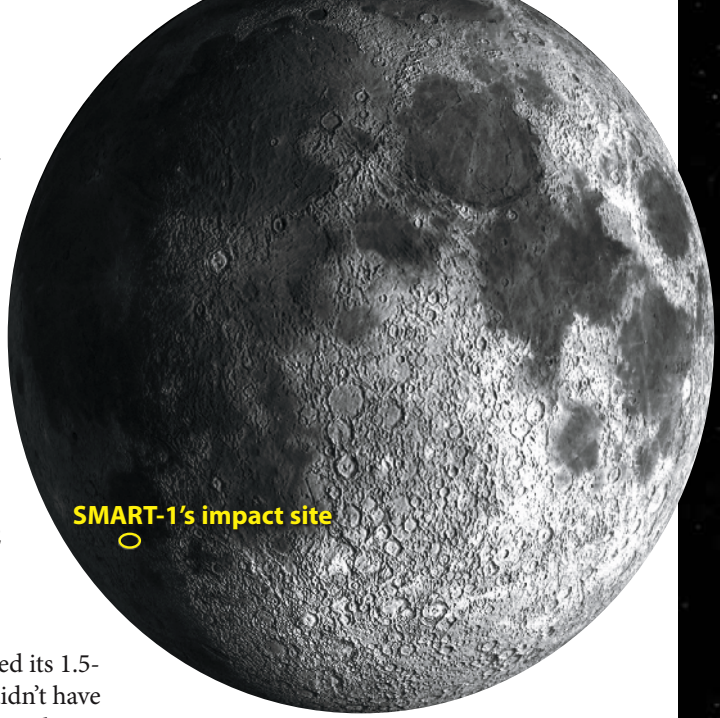
SMART-1 used D-CIXS in combination with another instrument called the X-ray Solar Monitor (XSM). This instrument watched for solar flares and X-ray emission from the Sun. To make accurate measurements of various elements, D-CIXS had to take into account variations in solar radiation intensity at the wavelengths it was monitoring. XSM acted as a calibration system for D-CIXS.

We nabbed two other firsts: detections of calcium from lunar orbit and titanium on the Moon's surface. We performed the calcium measurement north of Mare Crisium during the January 15, 2006, solar flare.

Testing, testing

SMART-1 carried additional instruments on board, ranging from equipment for communications to plasma science. The payload included the Spacecraft Potential, Electron and Dust Experiment (SPEDE), an instrument to observe the stream of charged particles emanating from the Sun. Both SPEDE and the Electric Propulsion Diagnostic Package (EPDP) monitored how the ion engine performed and if it interacted with any electric and magnetic phenomena in space.

A communications instrument called X/Ka-band Telemetry and Telecommand Experiment (KaTE) tested deep-space telecommunications between Earth and the spacecraft. Another experiment — Radio Science Investigation with SMART (RSIS) — tested how SMART-1's speed affected its radio signals. The Laser Link experiment tested communications via a deep-space optical laser link using an established ESA Optical Ground Station Telescope in Tenerife, Canary Islands. And the last of SMART-1's investigation — Autonomous Onboard Navigation (OBAN) — evaluated a system of autonomous navigation based on image processing. All this in 42 pounds (19 kg)!



Lacus Excellentiae (the Lake of Excellence) is near where SMART-1's journey ended September 3, 2006. This artist's impression shows the location of the SMART-1 impact. The impact likely created a crater 13 feet by 26 feet (4m by 8m) on the lunar surface. ESA/SMART-1/C. Carreau

Hard landing

After SMART-1 completed its 1.5-year science mission, it didn't have enough fuel to return to Earth or even escape lunar orbit. So, like many other lunar satellites, the probe would have naturally crashed into the Moon. Originally, the craft would have hit the Moon's farside. Instead, I proposed the SMART-1 operations team adjust the orbit to choose the exact time and place of impact: September 3, 2006, near Lacus Excellentiae (the Lake of Excellence) at mid-southern latitude. We chose an impact site on the Moon's nearside and encouraged observers on Earth to view the event. This was the first controlled lunar impact accompanied by real-time observations.

I coordinated an observing campaign involving observatories from North and South America, Hawaii, and the Canary Islands. SMART-1 hit the lunar surface at a grazing angle, just as planned. And it impacted within 1 second of our expectation. Using laboratory simulations, we also confirmed that the craft ricocheted off the surface. While some scientists predicted that ground observers wouldn't be able to see the impact, the Canada-France-Hawaii Observatory at Mauna Kea, Hawaii, did indeed detect a clear impact flash and debris clouds. Some amateur astronomers also saw the event, but unfortunately North America was overcast during the impact.

SMART-1's main science goals were to learn more about impacts on the Moon and also its composition. So observing a lunar impact — the ejected dust and the crater — helps us learn about both. The impact dug up materials that lie just beneath the lunar surface.

Because the SMART-1 mission has served as a test bed in many ways, what we learned from this controlled impact helped us prepare for NASA's Lunar Crater Observing and Sensing Satellite — scheduled to have launched in June of this year with the Lunar Reconnaissance Orbiter — in addition to future spacecraft impact observations. We've also put to use SMART-1 technology on already launched missions (such as China's Chang'e-1 and India's Chandrayaan-1), and we will incorporate it into the future ESA BepiColombo to Mercury. Our observations will also help humans prepare for a global robotic village and an international lunar base as the International Lunar Exploration Working Group recommends. Not bad for Europe's first time at the Moon.

Author Bernard H. Foing checks a prototype for future lunar or Mars rovers at ESA's ExoGeoLab. The lab, located at the European Space Research and Technology Centre in The Netherlands, is building on SMART lessons to develop landers, rovers, and instruments for lunar, planetary, and extreme-Earth-environment missions. ESA/ExoGeoLab/B. Foing

Ask Astro

Astronomy's *experts from around the globe answer your cosmic questions.*

What sculpts nebular shapes?

Q: What determines the particular shape of nebulae like the Dumbbell, Trifid, and Lagoon?
— **Cristian Lares,** Goldsboro, North Carolina

A: A nebula is a vast cloud of gas and dust. The physical processes that shape its appearance differ depending on whether it is an emission nebula or a planetary nebula.

Of the three examples you cited, the Trifid Nebula (M20) and the Lagoon Nebula (M8) are emission nebulae. Emission nebulae are glowing interstellar clouds. They shine because the stars within or near them emit ultraviolet radiation that energizes hydrogen in the clouds. The hydrogen atoms quickly release this energy as reddish light, giving emission nebulae their characteristic scarlet color.

In the Trifid Nebula (M20), three dense dust lanes cut across glowing gas clouds. The combination creates the object's distinctive appearance. Jim and Janet Castano/Adam Block/NOAO/AURA/NSF

Within some emission nebulae, radiation pressure outward from stars sculpts the gas from within and creates delicate and complex shapes. The region dubbed the "Pillars of Creation" in the Eagle Nebula (M16) in Serpens is a classic example.

Dust also contributes to the apparent shape of emission nebulae. The dust may darken certain areas of the cloud, as in the case of the Trifid Nebula's prominent triad of dust lanes.

In planetary nebulae, old stars cast off shells of gas and dust around themselves. A lone star typically forms a spherical cloud. If more than one star is involved, the shape grows increasingly complex.

For example, interactions between binary (paired) stars can form an elliptical nebula. If, however, the material cast off by one of the pair engulfs the companion star, butterfly patterns and other intricate shapes can develop. The interacting magnetic fields of the two stars also help sculpt the final shape of the nebula. — **Michael E. Bakich,** Senior Editor

BLACK HOLE CROSSING

Q: If a black hole crossed in front of a background star, could we see the black hole and determine its size? — **Jared Collard,** Fairfield Glade, Tennessee

A: There are probably a number of black holes traveling alone through our galaxy. **It is possible to detect and measure a black hole crossing in front of a star, although such alignments would be rare.**

The distances between stars (and black holes) in the galaxy are vast. Also, most black holes are relatively small — say around 60 miles (100 kilometers) across. These factors make chance alignments visible from Earth extremely unlikely.

However, if such a black hole crossing should occur, we could detect it if we were looking at the right spot at the right time. During the crossing, the black hole's gravity would "lens" the background star's light, causing it to bend inward. From Earth, the background star would appear to brighten slightly.

The change in brightness, combined with an estimate of how fast the black hole is moving across the background star, would make it possible to calculate the black hole's mass. — **Tod Strohmayer,** NASA's Goddard Space Flight Center, Greenbelt, Maryland

STELLAR NAME CALLING

Q: Do astronomers name and catalog individual stars in other galaxies? — **Charlie Flanders,** Zachary, Louisiana

A: Astronomers have observed, named, and cataloged a relatively small number of stars outside the Milky Way.

When astronomers do name a star, it's usually among the brightest and most massive members of a relatively nearby galaxy. These are the easiest to resolve with current telescopes.

The advent of large telescopes in the early part of the 20th century — the 200-inch reflector at Palomar Mountain Observatory, for instance — allowed astronomers to resolve individual stars in galaxies many millions of light-years distant. Edwin Hubble observed stars called Cepheid variables to estimate the tremendous distances to other galaxies.

However, in the case of relatively distant galaxies, telescopes usually cannot resolve stars from one another. Instead, we can see only the light collectively emitted by all the stars in the entire galaxy.

In a few cases, a star becomes visible in a distant galaxy when it explodes in a supernova and brightens by a factor of a billion or more. The star can briefly outshine the light from the rest of the galaxy, which allows astronomers to identify it as an individual star.

Supernovae are designated according to a standard naming convention. The supernova SN 1987A, for example, was the first supernova discovered in 1987.
— Cornelia C. Lang, University of Iowa, Iowa City

COSMIC CLOCKS

Q: Who first measured the speed of light? What method was used? **— Stan Barnes,** Grand Rapids, Michigan

A: Dutch astronomer Christiaan Huygens made the first calculation of light's speed. The estimate was based on observations of when Jupiter's shadow eclipsed its tiny moon Io.

As Io orbits Jupiter, it periodically disappears behind the planet's edge (an occultation) or enters its shadow (an eclipse). After Galileo discovered Io and Jupiter's other three large satellites (Callisto, Europa, and Ganymede), astronomers began to observe and record the exact timing of the moons' eclipses and occultations.

In 1672, Danish astronomer Øle Christensen Rømer began observing Jupiter's moons as assistant to the Italian-born French astronomer Giovanni Domenico Cassini at the Paris Observatory. The observations revealed that the timing of eclipses of the Galilean moons shifted with Earth's distance from Jupiter. As the distance increased, eclipses came later; as the distance narrowed, eclipses occurred earlier.

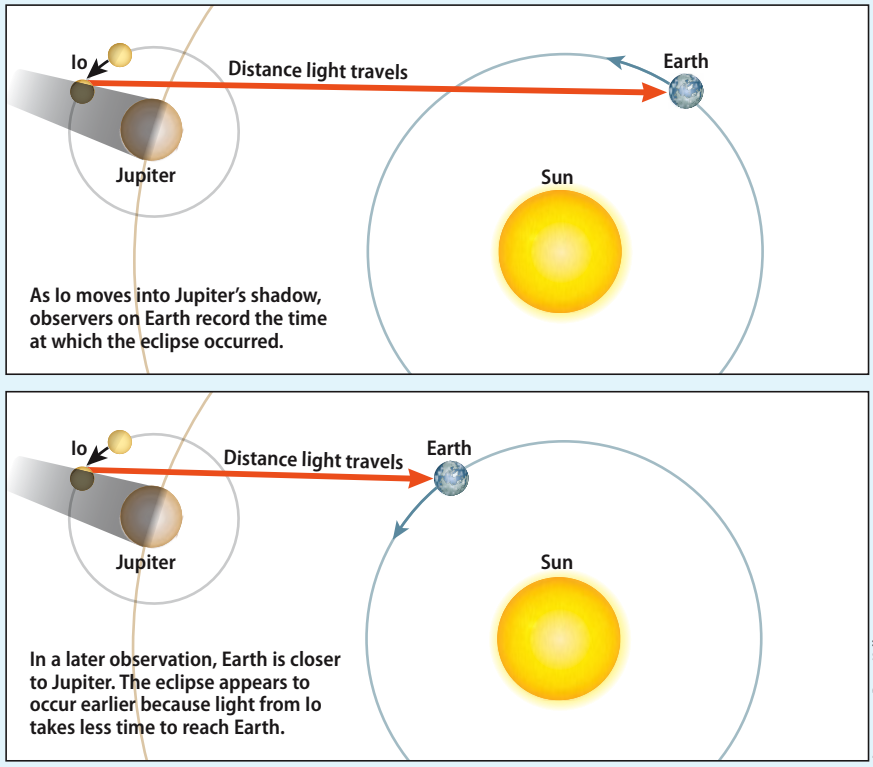
The explanation is that light's speed is finite — not infinite, as some believed. When Jupiter is farther away, Io's light takes longer to reach Earth, and therefore eclipses seem to occur later.

Cassini at first accepted but then rejected that light had a finite speed, but Rømer embraced it. In a paper published at the end of 1676, he attributed the timing variations in Io's eclipses to light's unchanging speed.

Rømer did not calculate the actual velocity. However, in 1678, Dutch astronomer Christiaan Huygens used Rømer's Io observations to clock light's speed at 230,000 kilometers per second, or roughly 143,000 miles per second. The precise modern value is 186,282.397 miles per second (299,792.458 km/s).
— Geoff Chester, U.S. Naval Observatory, Washington, D. C.

How warm does it get on Mars? Find out at www.Astronomy.com/toc.

Using Io's eclipses to measure the speed of light


Io
Distance light travels
Earth
Jupiter
Sun
As Io moves into Jupiter's shadow, observers on Earth record the time at which the eclipse occurred.
Io
Distance light travels
Earth
Jupiter
Sun
In a later observation, Earth is closer to Jupiter. The eclipse appears to occur earlier because light from Io takes less time to reach Earth.
Astronomy: Roen Kelly

Øle Christensen Rømer figured out that variations in eclipses of Jupiter's moon Io meant that light must travel at a set speed. The eclipses happened earlier when Earth was closer to Jupiter because light from Io had less distance to travel; they happened later when Earth was farther away. Combining Rømer's observations of Io and an estimate of the diameter of Earth's orbit, Dutch astronomer Christiaan Huygens made the first calculation of light's speed in 1678.

MAPPING THE PLANETS

Q: How do scientists determine the elevations of mountains and other topography on the Moon, Mars, and other places where there is no sea level as the reference point? **— Joe Tepera,** Muenster, Texas

A: On Earth, mean sea level is the reference for all elevation measurements. It's essentially the average level of the oceans without waves or tides. On the continents, sea level is where the water's surface would be if you dug a canal from ocean to ocean.

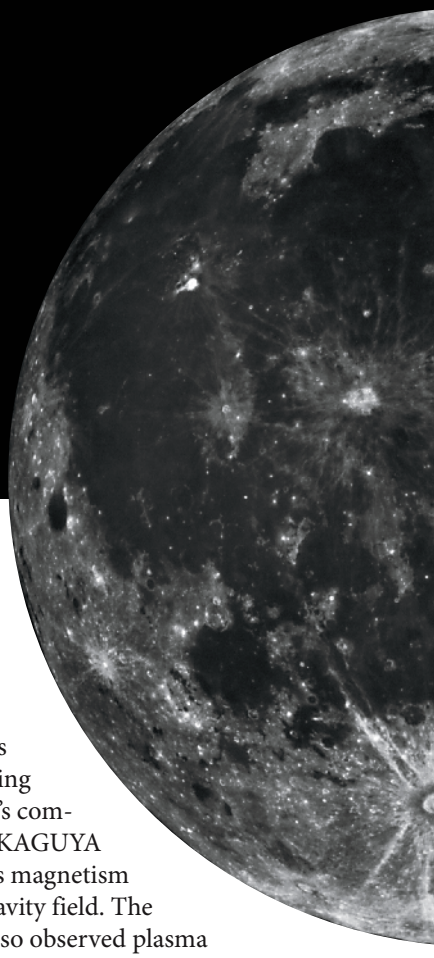
Elsewhere in the solar system, where there are no standing bodies of water, we normally use the planet or moon's average radius as a reference for measuring elevation. It's the shape the body would have if its rocky or icy crust were melted and then allowed to harden again. If such a global "shape model" of the body is not available, scientists may choose to describe the height or depth of a feature relative to some nearby location, such as a plain or valley.

Mapmaking gets more complicated on the moons of large planets like Jupiter and Saturn. The planets' powerful gravity distorts tiny satellites. In these instances it's still possible, using mathematics, to define an ideal reference surface for the moon that allows features to be mapped in a consistent way.

On gaseous planets like Jupiter, the body's shape is defined by the radius at which the atmospheric pressure is 1 bar, or roughly Earth's surface pressure.
— Paul Schenk, Lunar and Planetary Institute, Houston

Send your questions via e-mail to: **askastro@astronomy.com**; or write to **Ask Astro, P. O. Box 1612, Waukesha, WI, 53187.** Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.

Asia's new assault on the Moon



First-ever lunar missions from Japan and China returned valuable data and laid the foundation for more ambitious exploration. by Michael E. Bakich

In the fall of 2007, Japan and China separately launched their first space probes bound for Earth's natural satellite. The Japan Aerospace Exploration Agency (JAXA) KAGUYA (SELENE) mission departed for the Moon September 14, 2007. The Chinese National Space Administration (CNSA) followed suit with Chang'e-1 October 24, 2007.

Both probes carried equipment to study the Moon's surface composition as well as to peer underground. They also measured the Moon's immediate surroundings and the conditions that exist in the space between it and Earth.

Japan launches KAGUYA (SELENE)

KAGUYA (SELENE), which stands for the SELenological and ENgineering Explorer, the largest lunar mission since the Apollo program, lifted off on an H-IIA rocket. JAXA set high expectations for the mission's objectives: to understand the Moon's origin and evolution.

Besides investigating the Moon's composition, KAGUYA studied its magnetism and its gravity field. The satellite also observed plasma (ionized gas) and high-energy particles in the Moon's vicinity.

On the way to the Moon …

KAGUYA consisted of the main orbiter and two subsatellites. The first was OKINA, a small relay satellite. The other orbiter, OUNA, used radio transmissions to continually measure the distance between it and OKINA to a high accuracy. By comparing the two satellites' predicted and actual positions, scientists obtained a three-dimensional map of the Moon's gravitational field.

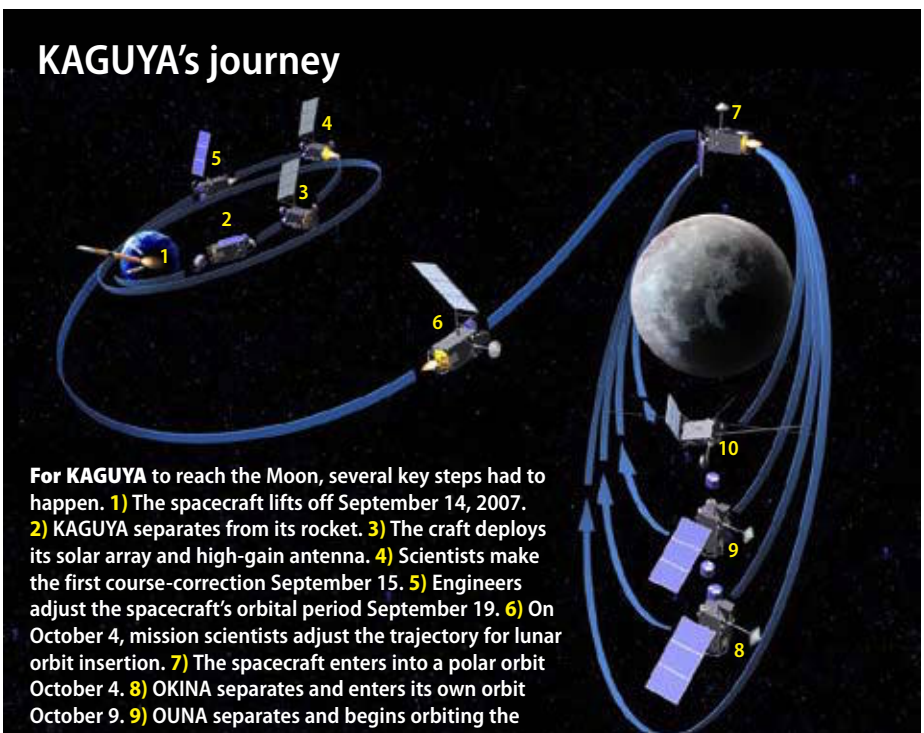
KAGUYA entered into lunar orbit October 4. It locked into a circular polar orbit at an altitude of 62 miles (100 kilometers) on October 18 as scheduled.

OKINA separated from KAGUYA October 9 and settled into an orbit ranging from 62 miles at its lowest to 1,500 miles at its highest. OKINA relayed signals from Earth to the orbiter and vice-versa when the orbiter was behind the Moon as seen from Earth.

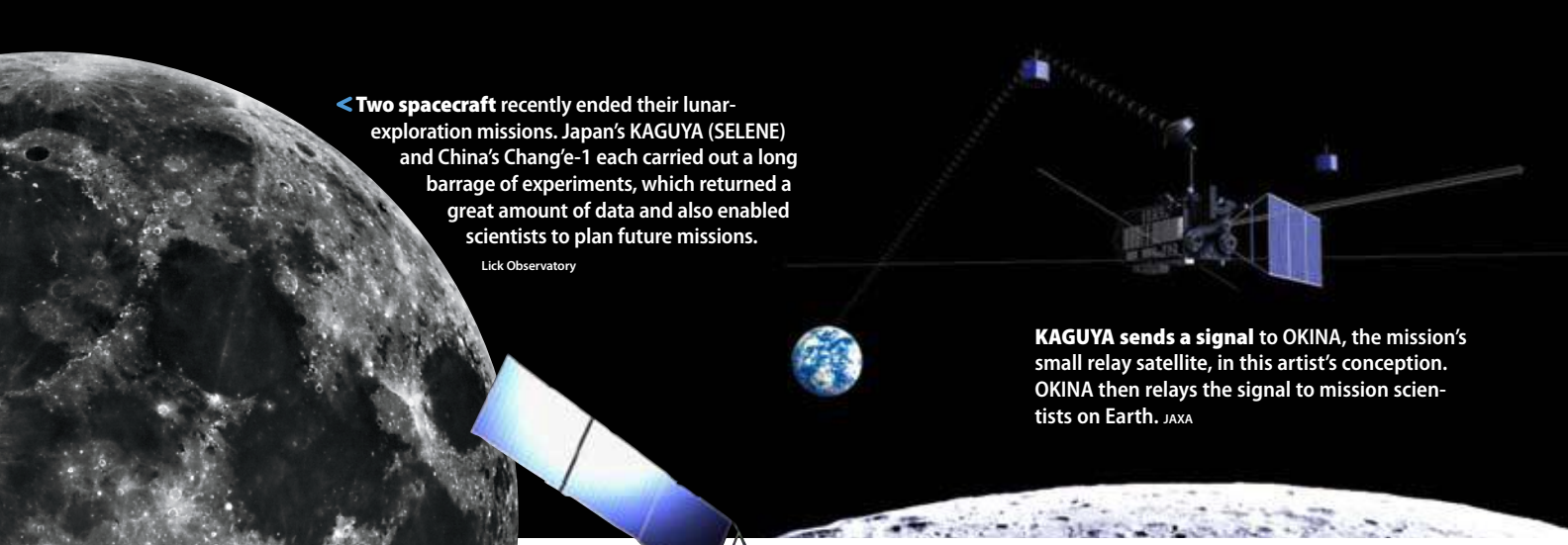
OUNA separated from KAGUYA October 12 and went into an orbit rang-

Michael E. Bakich *is a senior editor of Astronomy.*

KAGUYA's journey



For KAGUYA to reach the Moon, several key steps had to happen. **1)** The spacecraft lifts off September 14, 2007. **2)** KAGUYA separates from its rocket. **3)** The craft deploys its solar array and high-gain antenna. **4)** Scientists make the first course-correction September 15. **5)** Engineers adjust the spacecraft's orbital period September 19. **6)** On October 4, mission scientists adjust the trajectory for lunar orbit insertion. **7)** The spacecraft enters into a polar orbit October 4. **8)** OKINA separates and enters its own orbit October 9. **9)** OUNA separates and begins orbiting the Moon October 12. **10)** KAGUYA attains a circular lunar orbit October 18 and begins its observations. JAXA



< Two spacecraft recently ended their lunar-exploration missions. Japan's KAGUYA (SELENE) and China's Chang'e-1 each carried out a long barrage of experiments, which returned a great amount of data and also enabled scientists to plan future missions. Lick Observatory

KAGUYA sends a signal to OKINA, the mission's small relay satellite, in this artist's conception. OKINA then relays the signal to mission scientists on Earth. JAXA

> Every 127 minutes for 16 months, Chang'e-1 completed a lunar orbit 124 miles (200 km) above the Moon's surface. The spacecraft's mission lasted 16 months. CNSA

ing from 62 to 500 miles. The satellite measured and mapped the Moon's gravitational field.

Scientific results

Results from KAGUYA's Lunar Radar Sounder revealed layers several hundred meters below the surface in the wide, lava-filled regions called maria on the Moon's nearside. When scientists compared KAGUYA's findings to existing data, they announced that the prominent echoes are probably from buried regolith (loose material that covers solid rock) accumulated in the past 3 billion years.

The new gravity field data from KAGUYA suggests the Moon's farside has a more rigid lithosphere (crust and upper mantle). The basin structure KAGUYA recorded possibly reflects temperature differences throughout the layers. This data may help scientists understand how (and how fast) the Moon cooled.

KAGUYA's laser altimeter sent back data that allowed geologists to construct a new high-resolution lunar topographic map. The map shows that the Moon's highest point is on the southern rim of the Dirichlet-Jackson basin, which lies at 14° north latitude and 158° west longitude. The lowest point is in the Antoniadi crater, which lies nearly 70° south of the Moon's equator on its farside. The topographic range is about 12.31 miles (19.81 km), more than the last survey showed.

The craft's Terrain Camera (TC) provided high-resolution images to detect

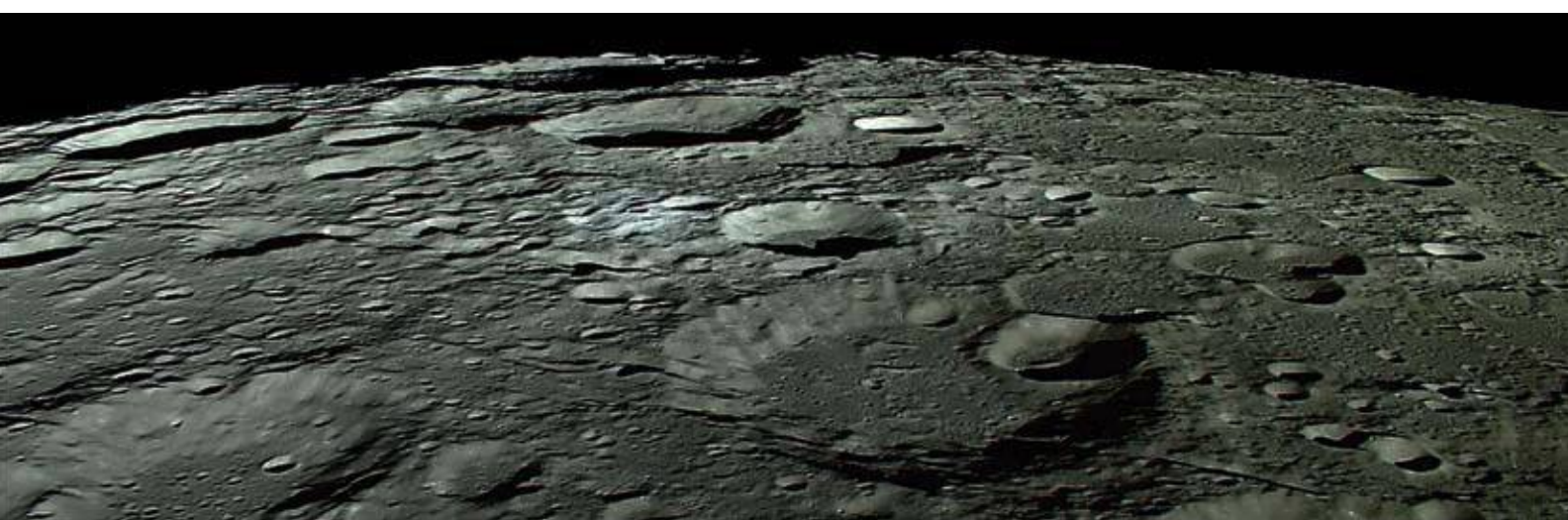
What's in a name?

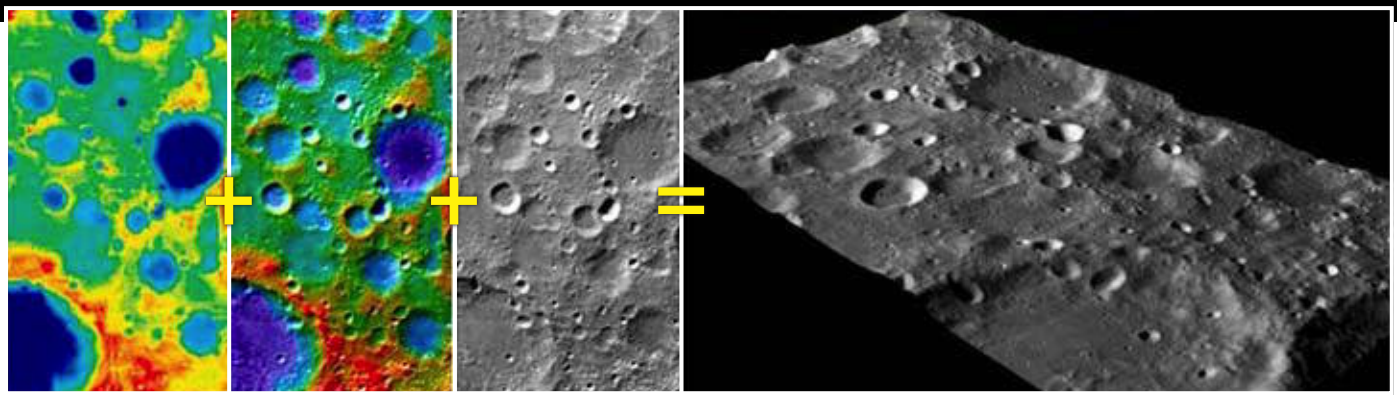
JAXA selected "KAGUYA" as the nickname for the SELENE spacecraft from 11,595 contest entries received. More than 1,700 people suggested KAGUYA. It originates from "Kaguya-hime" in "Taketori Monogatari" (The Tale of the Bamboo Cutter).

The folk tale says that an old bamboo cutter found a beautiful girl in a shining stalk of bamboo. The old man ("Okina" in old Japanese) and his wife ("Ouna," old woman) named her "Kaguya-hime" (Princess Kaguya). As she grew up, many men proposed to her, but she asked them to perform impossible tasks to prove their love. One night, a group of people appeared from the sky and returned Kaguya-hime to her home on the Moon.

Many of the contest entrants overlapped the images of SELENE going to the Moon on an exploration mission and Kaguya-hime going back to the Moon.

V KAGUYA (SELENE) produced the first high-definition video of the Moon from lunar orbit. The area shown in this image lies north of Oceanus Procellarum. Here, the low-Sun angle casts deep shadows into the craters. JAXA/NHK





This 3-D image of lunar terrain from Chang'e-1 released by the Chinese National Space Administration is a composite. Scientists took several false-color images and digitally combined them with one of the spacecraft's standard color shots. CNSA

Chang'e-1 blasted off on a 16-month lunar mission October 24, 2007, from Xichang Satellite Launch Center. The Chinese National Space Administration has designated Chang'e-1 the first of three lunar missions in a program expected to last until 2020. CNSA

small craters. As a result of this "crater-counting," several locations showed ages clustering at 2.5 billion years — about half a billion years younger than that of some other farside regions. Scientists think volcanic activity in those areas lasted longer than previously thought.

The TC also succeeded in the first 3-D imaging of 13-mile-wide (21 km) Shackleton Crater at the lunar south pole. The inside of the crater sits in permanent shadow, and radar observations by the Clementine spacecraft (launched in 1994) suggested that ice existed there.

The relay satellite OKINA impacted the lunar surface as planned February 12, 2009. At press time, JAXA expected KAGUYA to hit the Moon in June.

China launches Chang'e-1

A little more than a month after JAXA launched KAGUYA, China also sent a spacecraft to the Moon. Chang'e-1 is the first of a series of planned Chinese lunar missions. The spacecraft launched October 24, 2007, from Xichang Satellite Launch Center in Sichuan province. The CSNA named its program for a Chinese legend about a young goddess who flies to the Moon.

On November 7, Chang'e-1 entered into a 127-minute, 124-mile-high (200 km) circular orbit of the Moon. The CNSA planned for Chang'e-1 to orbit the Moon for a year to test the technology for future missions and to study the lunar environment and surface. Because all systems performed beyond expectation, the mission actually lasted 16 months.

Spacecraft and mission

Chang'e-1's payload included a stereo camera system to map the lunar surface, an altimeter to measure the distance to the surface, and a gamma-ray/X-ray spectrometer to study the overall composition and radioactive components of the Moon. Other equipment included a microwave radiometer to map the lunar regolith's thickness and a system of space environment monitors to collect data on the solar wind and the near-lunar region.

Chang'e-1 had four mission goals, and it accomplished them all. The first was to make 3-D images of lunar landforms and outline maps of major geological structures. This mapping included the first detailed images taken of some regions near the lunar poles.

Second, Chang'e-1 analyzed the abundance and distribution of 14 chemical elements across the lunar surface. Third, it measured the depth of the lunar soil, and fourth, it explored the space weather between Earth and the Moon.

The European Space Agency (ESA) collaborated with the Chinese on this mission by providing spacecraft and ground operations support services to CNSA. During ESA's SMART-1 mission, the agency provided the Chinese with the spacecraft's position and transmission frequencies. The Chinese, in turn, could test their tracking stations and ground operations by following it. This step was part of the preparation for Chang'e-1.

Chang'e-1's demise

Chang'e-1 successfully concluded its mission March 1 with a planned crash into the Moon's surface at 8h13m UT. The craft impacted the surface at 1.5° south latitude and 52.36° east longitude.

Next, the CNSA will launch Chang'e-2, scheduled for 2011, to deploy a lunar lander for exploration in a limited area. Finally, on the basis of the lander mission, the CNSA will implement a lunar sample return mission, Chang'e-3, perhaps as early as 2017. Officials expect the full program to last until around 2020.

Read about NASA's upcoming lunar mission at www.Astronomy.com/toc.

Earth's diamond ring blazed forth February 9, 2009, when KAGUYA used its high-definition TV camera to image our planet blotting out the Sun. At this moment, earthlings were watching a penumbral lunar eclipse (when the Moon enters Earth's lighter, outer shadow). This marks the first time a spacecraft caught this phenomenon from the Moon. JAXA/NHK

The Next Giant Leap...

The Time Has Come For Humanity To Journey To Mars!

The Mars Society is a visionary group of people dedicated to landing human explorers on Mars without further delay.

We need your support!

If you want to actively assist in building this next bridge into the Cosmos, log on to the Website listed below for membership sign-up and details on projects in progress.

You CAN Make A Difference — ***JOIN TODAY!***

THE MARS SOCIETY

MarsSociety.org

Meet with today's most prominent scientists, astronauts and leaders...

12th International Mars Society Convention

July 30 - August 2, 2009 - University of Maryland, College Park, MD, USA

Online Telescopes
LIVE Remote Control

Easy Interface
Take the tour at

MyTelescope.com

Special Rates
for our new site Grand Opening

Best Teaching Prize
(Celebrating 2009:IYA)

100 hrs of telescope time for your students!
more info at MyTelescope.com
Sky-Prize Contest

Thousands of $$$$$ in Awesome Giveaways!

So Cal's Largest & Most Exciting Astronomy Expo!

SCAE
SOUTHERN CALIFORNIA ASTRONOMY EXPOSITION

Grand Prize Donors:
Apogee • FLI • Stellarvue

Gold Prize Donors:
Orion • Meade • Canon • Celestron

Silver Award Donors: Astrodon • Astronomik • AstroZap Arizona Skyshack • Borg • Chronos • Coronado • Denkmeier Discovery • Explore Scientific • Farpoint • Hutech • Hotech Imaging Source • iOptron • JMI • Lunt • Optec • Pentax PlaneWave • QSI • Rigel Systems • SBIG • Sky & Telescope SkyWatcher • Star Chaserz • Takahashi • TeleGizmos Tele Vue • Vixen...and more!

SCAE Swap Meet & Star Party

Saturday, July 11th – 10am-11pm

At OPT:

- Manufacturers and local astronomy clubs will be selling at our astronomy swap meet (10am - 4pm).
- OPT will sponsor a showing of the movie "Journeys on Mars 3-D" followed by a special guest star and a public star party at Palomar College (6-11pm).
- Celebrating the International Year of Astronomy

SCAE Telescope & Astronomy Demo

Saturday, July 18th – 10am-7pm

At OPT:

- Over 30 manufacturers of the finest telescopes, CCD cameras, and other astronomical equipment on the planet.
- Listen to informative presentations, meet the reps, and get your FREE ticket for the OPT Giant Giveaway!
- Last year we gave away over $50,000 worth of equipment!

OPT

Oceanside Photo & Telescope
918 Mission Avenue • Oceanside, CA 92054

All Events are FREE!
optcorp.com/scae | 800.483.6287

Messier myths

Who was the real Charles Messier?

His catalog of deep-sky objects may be world famous, but most people don't know much about the man behind it. **by Ronald Stoyan**

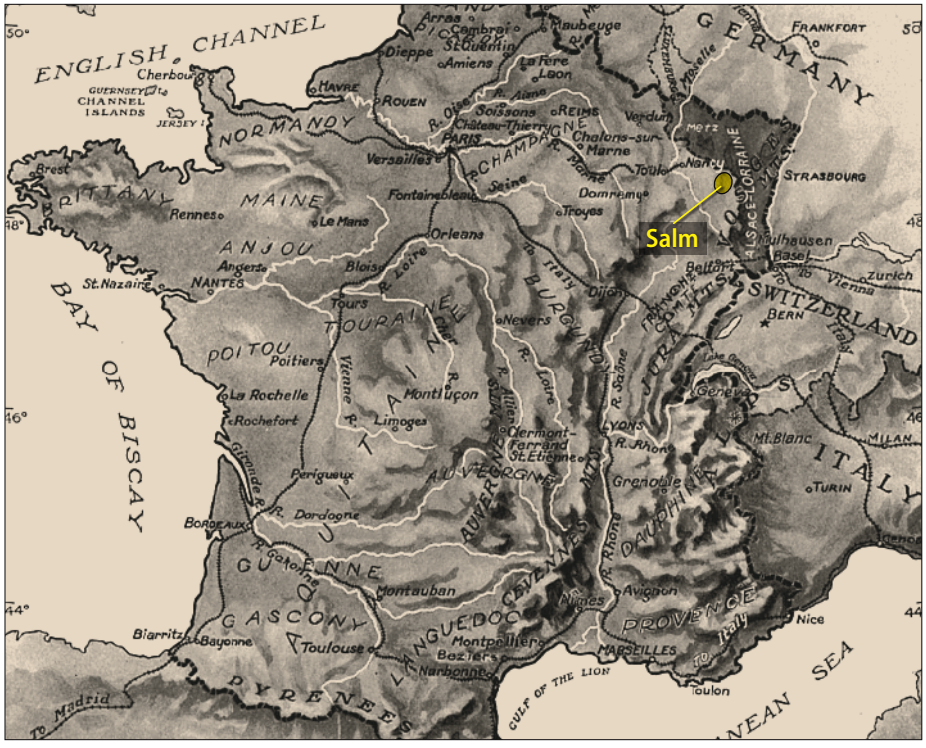
The Crab Nebula (M1) inspired Charles Messier to compile a deep-sky catalog. He found the Crab while searching for a comet in 1758. It looked so much like a comet that Messier decided to compile a list of nebulous objects so other comet-hunters could avoid similar confusion. R. Jay GaBany

Stargazers around the world rightly lionize 18th-century astronomer Charles Messier. After all, Messier compiled the most famous astronomical catalog of all time. Yet he and his work suffer from a fate that afflicts many historical figures: It's often hard to tell where reality ends and myth begins. Wonder no more. Here I present 10 common misconceptions about this famous observer and the truth that lies behind them.

MYTH: Messier's fatherland was France

Today we recognize Charles Messier (1730–1817) as one of history's greatest French astronomers. Yet Messier was not born a French citizen. He came from Badonville, a village of 1,500 people now located in the French Département Meurthe-et-Moselle. Back in 1730, however, Badonville belonged to the principality of Salm, an independent state on the border between France and Lorraine. Lorraine took control of the village in 1751; France annexed Lorraine in 1766.

The Messier family remained loyal to the princes of Salm. In 1751, when the princes moved their capital city to Senones just a few miles away, the Messier clan followed. Charles regularly visited his older brother Hyacinthe in Senones. In 1772, Charles wrote about Salm as "ma patrie" — his fatherland. France finally annexed the state in 1793 during the Napoleonic Wars.



Not a Frenchman at birth, Messier hailed from the small village of Badonville in the principality of Salm on the French border.

MYTH: He came from a poor family

The Messiers were an important and influential family in Salm. Charles' father, Nicolas, was a court bailiff; Hyacinthe became an auctioneer and later the chief financial officer in the state. Hyacinthe gave Charles an apprenticeship in his office that consisted largely of paperwork. This helped Charles develop writing and drawing skills. The attention to detail needed in finance and business later proved valuable in his observations.

When the family moved to Senones, Hyacinthe tried to find Charles a job elsewhere. With the help of a family friend, Charles became an assistant at the new Naval Observatory of Joseph-Nicolas Delisle in Paris. The offer came not because he had an interest in astronomy but because of his skills as an office assistant. He left Badonville September 23, 1751.

MYTH: Messier was a distinguished scientist

Delisle's humble observatory stood in the shadow of Paris' established Royal Observatory. This leading European institution

Ronald Stoyan *is the editor-in-chief of* Interstellarum*, one of Germany's leading astronomy magazines. He was the founding director of the German deep-sky organization "Fachgruppe Deep-Sky" and has authored or co-authored six books on practical astronomy. His latest publication is* Atlas of the Messier Objects *(Cambridge University Press, 2008).*

boasted great astronomers such as Christiaan Huygens and Giovanni Cassini. Delisle, by contrast, was not part of the French astronomy establishment. So Messier entered an environment that allowed him to pursue astronomical interests without any scientific obligations. Unfortunately, it also branded him as an outsider to professional astronomy.

In 1764, the English and Dutch scientific academies elected Messier a fellow. Such academies were crucial in the 18th century. Membership made it possible to correspond with leading scientists and gave access to their libraries. But Messier had to wait a long time before the French Academy of Sciences admitted him.

The astronomer's breakthrough came when he discovered the great comet of 1769. This spectacular apparition made its discoverer's name so popular with the general public that King Louis XV personally received a map Messier drew for him. The king nicknamed Messier "the comet nest-robber" because for many years not a single comet "slipped out of its egg" that Messier hadn't already discovered. This moniker later developed into his popular nickname: the comet-ferret.

MYTH: He was a deep-sky observer

Messier's first observational challenge was finding Comet Halley at its predicted return in 1758/9. During this search, he found and ultimately tracked a different comet: Comet de la Nux. While searching for this object in August 1758, the comet-hunter came across an object in Taurus that looked similar to the comet but did not move. It was August 28, 1758, and the astronomer had just discovered the Crab Nebula, now known as M1. He didn't know then that English observer Charles Bevis had seen the Crab back in 1731.

Messier later said: "What made me produce this catalog was the nebula which I had seen in Taurus, September 12, 1758 [when he measured the Crab's position], while I was observing the comet of that year. The shape and brightness of that nebula reminded me so much of a comet, that I undertook to find more of its kind, to save astronomers from confusing these nebulae with comets. I continued to observe with telescopes suitable for the discovery of comets, which was the purpose I had in mind when producing this catalog."

Charles Messier created the most famous catalog of deep-sky objects, but he devoted most of his energy to hunting for comets. Bibliothèque de l'Observatoire de Paris

Bibliothèque de l'Observatoire de Paris

Messier's observing logs showcase his drawing skills, honed during years working as an apprentice in his brother's finance office.

MYTH: Messier searched for nebulae systematically

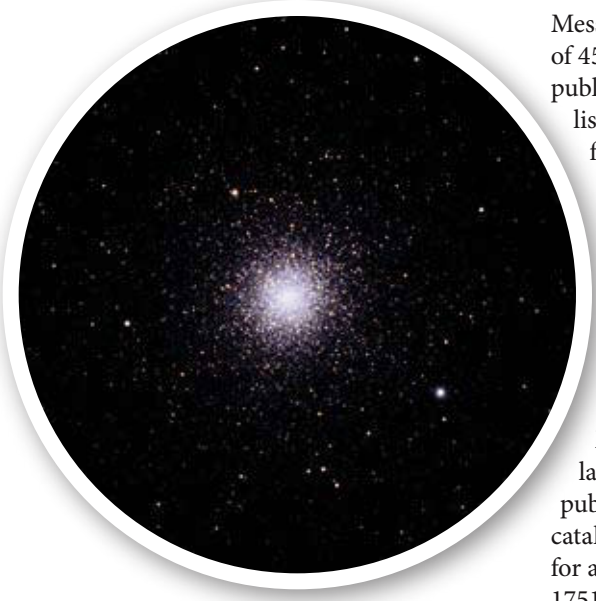
Messier was the first observer to systematically use a telescope to hunt for comets. Before him, most observers discovered comets with the naked eye. Between 1758 and 1804, he hunted for comets on more than 1,100 nights. He observed 44 comets altogether — more than the total known to science before him. He discovered 21 comets, six of which were co-discoveries.

Yet he did not search systematically for deep-sky objects. After he found M1, it took 2 years before he discovered the globular cluster that became M2 and

William Herschel started observing the deep sky not long after Messier did. But Herschel had a passion for finding "faint fuzzies" (which Messier didn't share) and discovered thousands of them. Bibliothèque de l'Observatoire de Paris

another 4 years until he came across M3. Messier published the final catalog in 1781 — a discovery rate that averaged about five objects per year.

This lack of interest separates him from William Herschel, who started to work on his impressive catalog in 1782. Herschel discovered a thousand objects in just 3 years and bagged another thousand by 1789. Still, when you consider Messier's often-accidental finds, his catalog is surprisingly complete.



Globular cluster M3 resolves into myriad stars when viewed through a modern telescope, but the telescopes in Messier's day rendered such clusters as fuzzy cometlike blobs. Neil Fleming

MYTH: He intended to extend his catalog

On November 6, 1781, Charles Messier was taking a walk when he slipped and fell 25 feet (8 meters) into a storage cellar. He was seriously injured, and it took him the better part of 1782 to recover. Herschel, who paid him a visit in Paris 20 years later, remarked that Messier never fully recovered from the injury.

Messier had to abandon all his work after his accident and did not resume his search for nebulae. In 1802, he described why: "After me, the famous Herschel published a catalog of 2000 [nebulae] which he had observed. Unveiling the sky in his way, with instruments of large aperture, is not useful for comet seeking. Hence, my objective is different from his: I only need the nebulae that are visible in a telescope of 2 ft [focal length]. I have observed more, meanwhile. I will publish them in the future, organized by right ascension, for the sake of finding them more easily, and so that those who are looking for comets have less uncertainty."

Despite his words, such a publication never came to be. There is no evidence that Messier observed more objects than those contained in his final list of 1781.

MYTH: Messier's was the first deep-sky catalog

Messier completed his first list of 45 "nebulae" in 1771 and published it in 1774. The second list, which added 25 objects, followed in 1780, and the third (and final) in 1781 contained 103 objects. Apart from some random listings, his was the first widely recognized catalog of deep-sky objects in the northern sky.

But with the southern sky, Messier was about 2 decades late. Nicolas Louis de Lacaille published the first real deep-sky catalog in 1755. He began observing for a southern star catalog in August 1751 from a site at the foot of Table Mountain, near present-day Cape Town, South Africa. (Lacaille named a new constellation Mensa [Latin for "table"] after the mountain.) He observed with a mural quadrant equipped with a telescope of 0.5-inch aperture and a magnification of 8x. By July 1752, this catalog contained the positions of 9,776 stars.

While cataloging the heavens, Lacaille made a list of the nebulous objects he came across. He published the list in 1755. In a world where most scientists congregated in the Northern Hemisphere, it's amazing that the first deep-sky catalog covered the southern sky. It clearly served as a model for Messier's own list.

Messier observed with small telescopes by today's standards. At the time, however, they were considered large. His favorite scope was a 3.5-inch achromatic Dollond refractor similar to this one. Ronald Stoyan library

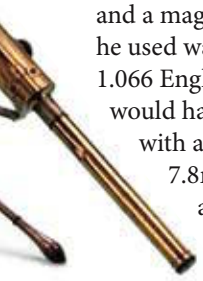
MYTH: Messier used only small telescopes

In Messier's day, most telescopes were puny by today's standards. Many astrono-

Nicolas Louis de Lacaille published a catalog of deep-sky objects nearly 2 decades before Messier did. Lacaille's list covered objects in the southern sky while Messier's was restricted to those visible from Paris. Bibliothèque de l'Observatoire de Paris

mers observed with telescopes no bigger than 2 inches in aperture. But Messier went well beyond that.

His first catalog (consisting of M1 to M45) contains exact descriptions of the telescopes and magnifications he used. In almost every one, Messier described the telescope as a Gregorian reflector of 30 inches focal length, 6 inches aperture, and a magnification of 104x. (The inch he used was an old French unit equal to 1.066 English inches.) Modern notation would have it as a 6.4-inch f/5 telescope with an eyepiece focal length of 7.8mm. This system would yield a field of view 17' across.



From 1771 on, Messier relied chiefly on a 3.5-inch f/12 achromatic refractor, which he described as his favorite instrument. He likely made his discoveries with smaller telescopes, which he used for comet-hunting. The larger optics let him make detailed observations and measure precise positions of the new objects.

MYTH: Messier did not suffer from light pollution

For some targets, Messier's observational impressions were so vague that he couldn't even determine the type of object. Some of the discrepancies are so big that some modern astronomers have started to doubt whether Messier saw the respective objects at all. One is the Trifid Nebula (M20), which Messier classified as a star cluster. Another is the Ring Nebula (M57), which the legendary observer thought consisted of stars.

Messier's visual talents may not be the problem, however. We simply may be underestimating the light pollution of nocturnal Paris in the 18th century. At the time, Paris was the world's largest city with a population of 800,000. Smoke from oven-heated houses, numerous factories, and open fires must have created air pollution considerably worse than today's, scattering and absorbing more starlight.

In addition, all public streets and squares were floodlit by oil-burning lamps from October to March. Not surprisingly, France sited the Royal Observatory (founded in 1667) outside Paris, but the Observatory of the Navy was in the central city. Messier's night sky likely was much worse than we imagine.

Paris was the world's largest city in 1771, when this map was made. The Royal Observatory was on the city's outskirts while Messier's humble observatory lay near the city center. Ronald Stoyan library

His notes give an impression of the light-pollution severity. By evaluating his observations with modern means, his naked-eye limit was around magnitude 5.5 — similar to a modestly light-polluted suburban sky today.

MYTH: The famous observer did not know the Double Cluster

Messier's catalog includes most of the night sky's showpieces, but a few stand out by their absence. Because these missing objects would have been within easy reach of Messier's telescopes, their omission puzzles many deep-sky observers.

The most prominent example is the Double Cluster in Perseus. In Messier's day, it was designated as Chi (χ) Persei. Messier must have known it — Ptolemy's *Almagest* mentioned it in the second century. And Messier's contemporary, Johann Bode, described its field as "to the north of the star χ a lot of small stars, looks nice in telescopes."

The puzzling question in this context is: Why, then, did Messier add four well-known and spectacular objects — M42 to M45 — to his initial list of 41? Certainly, no one would confuse them with a comet. In this instance, Messier probably was tempted to round up to a number larger than the 42 objects included in the list of his role model, Lacaille. But, at the same time, he didn't have enough showpieces to make it to the next higher round number, 50, so he left some out.

Perhaps Messier knew about the Double Cluster but omitted it from his catalog because it already had a proper designation. However, he made no notes about the Double Cluster, and he always marked χ Persei as a star on his published charts.

In the 250 years since Charles Messier spied the Crab Nebula, backyard observers have routinely invoked the great astronomer's name. The comet-ferret probably had no inkling that he would be remembered for a catalog of objects he had little interest in observing. Perhaps we owe him the courtesy of remembering who he was and what he accomplished, and to banish these old myths.

Equipment review

Orion's truss-tube scope offers power and portability

With the help of Orion's SkyQuest XX12 reflector, finding faint deep-sky treats just got easier. **by Phil Harrington**

The SkyQuest XX12 IntelliScope combines a 12-inch reflector with a truss-tube Dobsonian mount. Orion includes a computerized object locator with a database of 14,000 objects. All photos: *Astronomy*: James Forbes; background image: Tony Hallas

Internet astronomy forums were abuzz last fall with speculation about the new flagship telescope that Orion Telescopes and Binoculars was about to unveil. When the curtain went up, we saw the SkyQuest XX12, a 12-inch f/4.9 Newtonian reflector complete with Orion's IntelliScope object-location system.

The XX12 is Orion's first Dobsonian-style telescope with an open truss-tube design. Recently, I had a chance to put the XX12 through its paces, and I must say that I came away impressed.

Assembly and collimation

The instrument arrived in three boxes. The largest contained all of the components for the telescope's optical tube assembly except the primary mirror. That came safely packed in a second box, and the Dobsonian base was in a third. Assembly took about 2 hours. The owner's manual, which is clearly written and amply illustrated, detailed every step along the way.

Placing the assembled optical tube into the cradle of the Dobsonian base takes a little getting used to. You must lower it vertically so that the two altitude bearings rest on the matching Teflon pads. You have to avoid getting it hung up on the altitude encoder's protective bumper. Practicing during the daytime made it easier to do at night.

After you have assembled the XX12, the final step is to check the instrument's collimation (optical alignment). For an f/4.9 truss-tube reflector like the XX12, you should check its collimation before each use, especially if you have carried it to your observing site. That's why Orion includes a simple alignment tool that fits into the focuser's draw-tube. By following the directions in the manual, the observer works backward from the secondary mirror to the primary mirror until everything lines up correctly through the alignment tool's peep sight.

Phil Harrington *is a contributing editor of* Astronomy. *He enjoys observing through large telescopes.*

The XX12 disassembles into four main components: the Dobsonian base, the upper and lower truss assemblies, and the truss-pole set.

Sky-testing

I took the scope outside to let the primary mirror cool. Hastening this step is a fan that mounts to the mirror cell, an excellent accessory. The XX12 comes with two eyepieces: a 35mm DeepView 2", which provides a magnification of 43x, and a 10mm Plössl 1¼", which gives 150x.

The constellation Orion was high in the south, so I swung the telescope toward the Orion Nebula (M42), which lies in the Hunter's sword. The view through the 35mm eyepiece was that evening's "wow" moment. Faint tendrils of nebulosity filled the field. It was striking.

Trying to maintain my objectivity, however, I couldn't help but notice that

Contact information

Orion Telescopes and Binoculars
89 Hangar Way
Watsonville, California 95076
[t] 800.447.1001
[w] www.telescope.com

the stars across the outer half of the field were warped. That speaks more to the eyepiece's quality and not that of the telescope. Fast focal-ratio optical systems like the XX12's require premium low-power eyepieces to minimize distortions.

Changing over to the 10mm Plössl eyepiece, I zeroed in on the Trapezium, the small star cluster within M42. The four main stars, as well as their two fainter companions, were all pinpoint sharp and easily resolved.

Because the seeing was especially steady that night, I thought I'd see just how far I could push the scope. Returning to the Trapezium with a 5mm eyepiece (300x), I noted that the image remained sharp and clear. Even boosting to a ridiculous magnification of 700x didn't compromise the view, a testament to the XX12's optical excellence.

Sharp focus was easy to achieve, thanks to the XX12's smooth dual-speed Crayford focuser. I appreciated that the focuser's right-hand knob includes both coarse and fine adjustments. Some dual-speed focusers are designed so that the left knob is coarse-focus only and the right is fine-focus only, or vice versa. I'm a creature of habit and would rather do all the focusing with one hand rather than have to switch back and forth.

The only negative experience I had with the XX12 came during the first night when the IntelliScope's azimuth readings were erratic. The next day, I conducted diagnostic tests recommended by the owner's manual. I traced the problem to the small encoder disc used to measure azimuth motion. For the IntelliScope computerized control to work properly, the spacing between the encoder sensor and disc must be set precisely by tightening the azimuth axis lock-nut as detailed in the instructions. If the nut is too loose or too tight, the spacing will be off and the readings will be incorrect. After correcting the spacing, I tried the scope again the following evening. Sure enough, the accuracy improved enough to get most targets within the field of the 10mm eyepiece.

Specifications

SkyQuest XX12 IntelliScope

Type: Newtonian reflector
Mount: Dobsonian truss-tube
Primary mirror: 12 inches (305mm)
Focal length: 1,500mm
Focal ratio: f/4.9
Tube length: 58.3 inches (1,481mm)
Weight, optical tube: 49.5 pounds (22.5 kg)
Included: IntelliScope object locator with 14,000-object database, 2" dual-speed Crayford focuser with 1¼" adapter, 9x50 finder scope, 35mm and 10mm eyepieces, cooling accelerator fan, 12-volt battery pack for fan, collimation cap, dust covers, *Starry Night Special Edition* software
Price: $1,299.95

The optics of the XX12 yield an f/4.9 system with a focal length of 1,500 millimeters. The included finder scope is Orion's 9x50 model.

I give this scope an "A"

I came away impressed with Orion's XX12. In it, intelligent design and high-quality components come together to create one of the finest instruments of its size sold today. If you're a visual deep-sky observer like me and are looking for a telescope that will enthrall you for years, the XX12 should be on your short list of candidates.

Orion includes a 2" dual-speed Crayford focuser with a 1¼" adapter. Two eyepieces come with the telescope: a 35mm 2" DeepView (which yields 43x) and a 10mm 1¼" Sirius Plössl (150x).

Evening Stars
by David H. Levy

A great's life

Celebrate Galileo Galilei and how he moved science forward.

The International Year of Astronomy is really about Galileo. It's not because he was the first to look through a telescope — remember, last month we discussed the English perspective glass that was in use decades earlier. It's because he was the first to carefully record what he saw, promptly publish his work, and accept the consequences of the conclusions he drew.

Galileo was born in 1564, the same year as William Shakespeare. His first name derives from a Tuscan custom of the era that the first name of the firstborn child would be a repeat of the surname. Although Galileo lived to age 78, extraordinarily long for his time, he was often ill with arthritis or rheumatism.

Galileo was well past mid-career when he looked at Jupiter January 7, 1610. He wrote, "I perceived … three starlets, small indeed, but very bright." Certain that these were "fixed" stars, he enjoyed his view enough that on the next night he sought them out again. The starlets had moved with respect to Jupiter, and over the next few evenings they moved enough to convince Galileo that they were moons circling their planet.

Later in 1610, Galileo used his telescope to record the positions of sunspots crossing the full diameter of the Sun. Although he did not use a filter, he likely performed his observations near sunrise or sunset, when the natural atmospheric haze dims the Sun slightly. The poor quality of his objective lens probably also acted as a sort of filter.

The author's Galileo telescope replica sits to the left of his 16-inch scope. Peter Manly of Phoenix, Arizona, made it out of cardboard and wrapped it with butcher paper. David H. Levy

Galileo was held under house arrest during the final years of his life in his villa in Arcetri, Italy, south of Florence. David J. Eicher

But it was a third discovery that sealed Galileo's fate. Throughout the fall of 1610, as Venus shone in the evening sky, it revealed its phases through Galileo's optical tube. This meant that Venus must orbit the Sun, and Earth isn't at the center.

Galileo lived to see his friend, Maffeo Barberini, elected Pope Urban VIII in 1623. The new pope couldn't wait to see his scientific friend.

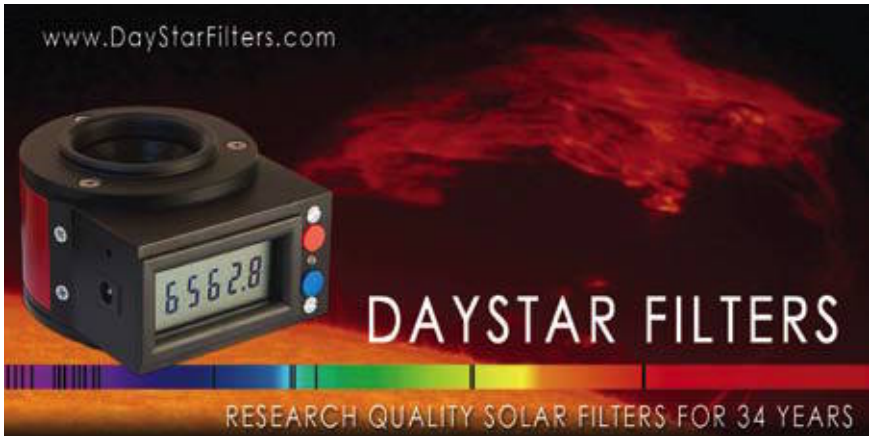
The pope's early years were a victory for Galileo. He and Urban VIII took long walks on the grounds and discussed all manner of scientific questions. Although Galileo understood that he was no longer talking with Barberini but with Pope Urban VIII, he felt reassured by the pope. In 1632 Galileo published his interpretation of his 1610 discoveries in the form of a conversation called *Dialogue Concerning the Two Chief World Systems*. In the publication, Galileo presented the pope's arguments against the Copernican system in the voice of a simple fool. The publication enraged the pope, who summoned Galileo to appear before the Inquisition.

It was a catastrophe for Galileo. Even as he awaited trial, he was led to believe that he would get off with something like a reprimand. However, at the end he was sentenced harshly. Convinced that Galileo had duped him into granting permission to publish a book that made him look foolish, the pope sentenced Galileo to life imprisonment. Galileo begged for a lighter sentence, which the pope quickly granted: life imprisonment within the scientist's villa in Arcetri while a representative of the Inquisition kept tabs on Galileo's activities.

Some years later on a fall afternoon in 1638, a young English poet named John Milton visited Galileo. How I wish I could have eavesdropped on the conversation between two men whose instruments — a telescope and a pen — and words spoke to the ages. Years later, Milton's *Paradise Lost* mentions the names of many angels, but only one human — the man named Galileo.

In this year of astronomy, Galileo remains an enigma. The controversies that plagued his later years have vanished, and he is now regarded universally as one of the greatest scientists of all time, well positioned with Newton and Einstein. As recently as 1992, Pope John Paul II declared after a 13-year investigation that the Catholic Church wrongfully condemned Galileo. Father George Coyne, then director of the Vatican Observatory, told me that John Paul may have chosen this path rather than risk a second trial of Galileo.

"The error of the theologians of the time," John Paul noted, "when they maintained the centrality of the Earth, was to think that our understanding of the physical world's structure was, in some way, imposed by the literal sense of Sacred Scripture." The world had changed, and now 17 years later the church is enthusiastically on board with the modern world's celebration of Galileo's great deeds — and his courage.



Woodland Hills Telescopes

Order: Mon-Sat • 9-6 PT
Toll Free: 888.427.8766
P: 818.347.2270
F: 818.992.4486
TelescopeS.NET

5348 Topanga Canyon Blvd.
Woodland Hills, CA 91364

SERVING THE ASTRONOMICAL COMMUNITY FOR OVER 20 YEARS!

WE HAVE STELLAR SOLUTIONS FOR ALL YOUR ASTRO NEEDS!

NEW lower prices!

Order your 6" ETX-LS Today!

LX200-ACF GPS

LX90-ACF GPS

MEADE NEW low price on MySky!

CPC

Nexstar 8 SE

SkyScout Personal Planetarium

New CGE Pro

CELESTRON SkyScout IYA limited edition in stock!

$399*
14mm 100° Series
Nitrogen-Purged
*Limited Quantity at this Price

82° Series
30mm $349
24mm $299
18mm $199
14, 11, 6.7, 4.7mm $149 ea.

EXPLORE SCIENTIFIC
PREMIUM EYEPIECES

Vixen Optics
BT125
$3,995
In Stock!

GP2 w/VMC200
$1,695
Regularly priced $3,495

Vixen 80ED O.T.A. $399

TAKAHASHI
The Triplet Ed Appochromatic will delight you with color free images
TSA 102S
XX12
StarShoot Pro

CORONADO
We now have the new Personal Solar Telescope, P.S.T.-CaK, in our store. It allows you to see and photograph solar flares and prominences safely. $495
P.S.T.

NEW lower prices on most Coronados!

EXPLORE SCIENTIFIC
Denkmeier
JMI
KENDRICK ASTRO INSTRUMENTS
Leica
LOSMANDY
MoonLite Telescope Accessories
ORION
PENTAX Scope, Eyepieces
SBIG
SKY COMMANDER
Thousand Oaks Optical
AND MANY MORE!

WIN A FREE TELESCOPE! ENTER AT www.TelescopeS.NET

THE ULTIMATE IN ASTRO SHOPPING:
www.adorama.com

FREE Shipping
On ThousandS Of Products
See our web site

PREMIER SELECT CELESTRON DEALER

CPC Series
XLT Starbright H.P. Schmidt Cassegrain Telescope with NexStar Computer Control & SkyAlign Technology
Tomorrow's next generation 8, 9.25, and 11 computerized GPS SCT's are here now!

NexStar SE

NEW! Nexstar SE Series 4SE, 5SE, 6SE, 8SE,
INCLUDES:
• XLT Coatings
• Orange Removable OTA,
• 40,000 object database,
• Nexstar Remote Software,
• The Sky Software
• Adjustable Tripod

SkyAlign

STARTING AT
$599.00

CGEM Computerized Mount
NEW
• Ultra sturdy 2" steel tripod with Accessory Tray
• Payload Capacity of 40 lbs
• The CGEM mount has a fresh, attractive, bold appearance and is capable of carrying Celestron's higher-end SCT optical tubes (up to 11") securely and vibration free which is ideal for both imaging and visual observing.

CELESTRON TELESCOPE ACCESSORIES

NexImage
Solar System Imager
NEXIMAGE ACCESSORIES
UV/IR CUT OFF Filter 52.95
Neximage Reducer 21.95
2x Ultima Barlow Lens 60.95

$99.95

EYEPIECES KITS

Includes: • 5 Superior Grade Plossl Eyepieces 1.25"(4mm, 6mm, 9mm, 15mm, & 32mm), • 2x Barlow Lens, • Six Colored Filters, • Moon Filter, • Aluminum Carrying Case

2" ACCESSORY KIT
Includes: • 3-2" Eyepieces, 2" 5 Color Filters, 2"Star Dia, 2" 2X Barlow Aluminum Case

BINOCULARS

25 x 100 SkyMaster, Weather Resistant Porro Prism Binocular with 3.0 Degree Angle of View, U.S.A.
• Waterproof
• BAK-4 Porro
• Multicoated Optics
• Long eye Relief
• Integrated Tripod Adapter
• Structural reinforcement of the main body for maximum stability
Celestron No Fault Limited Lifetime warranty

CELESTRON SKYSCOUT

SKYSCOUT PERSONAL PLANETARIUM

Introducing the SkyScout from Celestron: The SkyScout is a revolutionary, one of a kind, patented handheld device that instantly identifies and/or locates any celestial object visible to the naked eye, providing educational and entertaining information, both in text and audio.

A fun learning tool for all ages, the SkyScout personal planetarium puts the knowledge of an expert astronomer in the palm of your hand.

Item Includes: Carry Case, Earphones, Hand Strap, USB Cable

ADORAMA INC.
Source for the Educated Photographer

Secret Sky

by Stephen James O'Meara

Moonbows: architecture of light

If you have a dark sky and misty air, be on the hunt for a lunar rainbow.

"... she sought the shadow of iris where the bow should be. Steadily the colour gathered, mysteriously, from nowhere, it took presence upon itself, there was a faint, vast rainbow. The arc bended and strengthened itself till it arched indomitable, making great architecture of light and colour and the space of heaven, its pedestals luminous ... its arch the top of heaven."
— D. H. Lawrence, *The Rainbow*

These words capture the visual poetry of seeing nature construct a daytime rainbow. Except for the greatness of color, Lawrence's words from his 1915 novel could also describe nighttime's phantom moonbow, a sufficiently rare naked-eye phenomenon — but one well worth the hunt.

The sight of a lunar rainbow can cause an adrenaline rush strong enough to make the heart leap and the mind wonder.

Rainbow bridge

Lawrence's "shadow of iris" refers to Iris, the Greek goddess of rainbows. A servant of the Olympian gods, she could transport messages between gods and humanity. By joining them, she restores peace to nature. (In similar fashion, some people grieving the loss of a pet find solace in the mythical "rainbow bridge," which they will one day cross with their deceased pet(s) into heaven, as the popular poem of the same name suggests.)

In Maurus Servius Honoratus' commentary of Virgil's *Aeneid*, Servius Tullius (the sixth legendary king of ancient Rome) says that a rainbow was the road on which Iris would travel, appearing whenever the goddess willed it and vanishing when it was no longer desired.

However, "if Iris holds sway by day in such a favored rainbow haunt," writes Guy Murchie in his 1954 book, *Song of the Sky*, "it is Hecate who takes her place at dusk — Hecate, pale goddess of nightly apparitions, proprietress of the ghostly moonbow."

You do not need a hard rain to capture a moonbow. The author took this blue-sky moonbow as a fine mist, preceding a passing shower, overtook him. Note the faint luminous band inside the moonbow — a supernumerary bow. All photographs by Stephen James O'Meara

A lunar halo surrounds the Moon and has a radius of 22° — about the size of a fully outstretched hand (from pinky to thumb) held at arm's length. Light interacting with ice crystals high in the atmosphere creates this phenomenon. A moonbow is a different phenomenon that appears opposite the Moon.

In some versions of the myth, Hecate, the "Queen of Ghosts," guards the twilight zone between the normal world and the spirit world. Greek vases commonly depict her as a woman holding two torches, symbolic of the dual worlds; in other images, twin ghost hounds accompany her. Inspiration for these depictions may have come from another ghostly sky spectacle: the two moondogs of a lunar halo (see *Astronomy*, December 2007, pp. 20–21) — a phenomenon sometimes mistaken for a lunar rainbow.

The moonbow

A moonbow is a rainbow created by moonlight rather than sunlight. The physics are the same. Moonbows result from the refraction and reflection of moonlight in water droplets. To see one, the Moon must be in clear (or clearing) sky behind you. Water droplets must be ahead of you and cover enough sky for the phenomenon to appear. And it must be dark enough.

Under the best conditions, you can see at least two lunar bows: the "primary" and "secondary." The primary bow is the brighter of the two. It results from two refractions and one reflection in each

raindrop. Light bends (refracts) on the way into the drop, reflects once inside, then refracts once more on the way out. Light diverges as it exits each drop and forms the primary with a 42° outer radius. The secondary bow results from two refractions and two reflections, producing a bow with a 51° inner radius. So the weaker secondary bow lies about one fist higher in the sky than the stronger primary bow. Between them is a dark region, called "Alexander's Dark Band."

To see the primary and secondary bows, look 42° and 51°, respectively, away from the "antilunar point" — the point directly opposite the Moon. Lunar rainbows, therefore, achieve their greatest height at the times of moonrise or moonset when the antilunar point rests on the horizon opposite the Moon. As the Moon rises in the eastern sky, the moonbow sinks in the west.

The opposite happens around the time of moonset. As the Moon sinks toward the western horizon, the moonbow rises in the east. When the Moon sets, the ghostly bow vanishes. Thus, under normal conditions, you have two brief windows of opportunity on any given misty day to see a moonbow. How much of an arc you see depends on when you look.

Ghostly color

At a glance, a lunar rainbow is a pale white arc for the same reason other dim objects usually appear colorless at night. But try alternating your gaze between direct and averted vision. Sometimes, especially around the time of Full Moon, a primary bow will shine intensely enough to stimulate the color-sensitive cone cells in your eyes.

As the Full Moon rose, the author captured this double moonbow from the summit of Kilauea Volcano on the Big Island of Hawaii. While many moonbows appear colorless to the unaided eye, photographs can capture their full spectrum of colors.

One of the earliest accounts of moonbow color appears in the Rev. C. C. Clarke's 1821 book, *The Hundred Wonders of the World, and of the Three Kingdoms of Nature*. In it he describes a "very rare phenomenon" witnessed at Glapwell Hall in Derbyshire, England, at about 8 P.M. on Christmas Day, 1710. Clarke writes of an "iris lunaris" with "all the colours of the solar iris, exceedingly beautiful and distinct, only faint in comparison with those which are seen in the day … the entireness and beauty of its colours furnished a charming spectacle."

Seeing a full spectrum of light in a moonbow is rare. More commonly, its pallid green inner band gradually diffuses into a pale orange outer band. But the bow's full range of spectral radiance will appear in photographs. As with the daytime rainbow, the primary moonbow's inner edge shines with cool blue-violet light while its outer edge burns orange-red. The reverse is true for the secondary bow.

Moonbows don't need a Full Moon to appear. On the evening of November 13, 2007, the author snapped this shot of a lunar rainbow when the waxing crescent Moon was only 4 days, 6 hours after new. The photo captured a faintly colored bow crossing Perseus and Comet 17P/Holmes. The sky was quite dark at the beginning of nautical twilight (when the Sun is 12° below the horizon).

A moonbow challenge

The best moonbow displays occur at Full Moon. But unless you're away from city lights, they may be difficult to see. Moonlight is about 400,000 times fainter than sunlight. Therefore, any imposing artificial light can banish Hecate's ghosts to the visual netherworld.

Contrary to popular belief, moonbows do not belong only to the Full Moon. Under the darkest skies, you can see them from the light of a waxing or waning Moon. But how small a Moon will create a moonbow visible to the unaided eye? To the photographic image? Les Cowley of Atmospheric Optics (http://www.atoptics.co.uk/) and I would like to know. Les says, "The current photographic/naked-eye record is a bow made by a crescent just 4 days, 6 hours old. Can you improve on that? The prize is not yet decided — maybe an umbrella!"

I'm also interested in hearing about using artificial rain to create moonbows. The moonbow's arc is part of a greater circle. The rays from the moonbow form a cone around an imaginary axis that leads to your eye. If you view the mist from a garden hose under moonlight, you can make a nearly complete circular moonbow a few yards across. Be sure to send your reports to me at someara@interpac.net and to Les at atoptics@gmail.com.

Good luck!

Astronomy.com

brings the sky above to you with these great subscriber-only benefits:

- StarDome Plus, an enhanced StarDome for subscribers, displays comets, asteroids, stars, deep-sky objects, and more
- Atlas of the stars, an interactive sky chart with the capability of zooming in on 24 overlapping maps
- The sky this month, an observation calendar, tells you about gaze-worthy sky events occurring throughout the month
- Ask Astro, the informative source that answers reader questions with expert, in-depth explanations
- Our multimedia gallery, a vast collection that brings the "sounds of the sky" to life with pictures, movies, and audio
- Plus many more Web site extras available **only** to *Astronomy* magazine subscribers

Visit Astronomy.com today to become the observer you always wanted to be!

Astronomy

CIR-ADH-O8X1115RH

New Products

Binocular Photon Machine

Night Vision Astronomy
Pound Ridge, New York

Night Vision Astronomy's Binocular Photon Machine (BIPH) turns one photon into 50,000 electrons, effectively increasing your telescope's aperture. Optional camera lens adapters let you use the BIPH hand-held. Each BIPH comes in a high-quality Pelican case.

Price: $3,995 (new); $3,299 (used)
[t] 646.772.4138
[w] www.nightvisionastronomy.com

4.7mm 82° eyepiece

Explore Scientific
Laguna Hills, California

Explore Scientific's 1¼" 4.7mm 82° Series Eyepiece combines high-refractive-index and low-dispersion optical glass. Explore Scientific multicoats all optical surfaces, and the internal surfaces are flat black. Eye relief is 14mm. The eyepiece weighs 9.2 ounces (0.26 kg).

Price: $149
[t] 888.599.7597
[w] www.explorescientific.com

80mm spotting scopes

Swarovski Optik North America
Cranston, Rhode Island

Swarovski Optik's magnesium-body spotting scopes are available with straight (STM 80 HD) or angled (ATM 80 HD) bodies. The scopes' fluoride lenses are fully multicoated. Swarovski filled the dustproof, watertight tubes with nitrogen to prevent fogging.

Price: $2,599
[t] 800.426.3089
[w] www.swarovskioptik.com

Sloan-inspired u' filter

Astrodon
Orangevale, California

Astrodon based its Photometrics series filters on the ones developed for the Sloan Digital Sky Survey. All filters have peak transmissions in excess of 95 percent. The 1¼" u' filter covers the ultraviolet end of the spectrum.

Price: $150
[t] 916.712.2559
[w] www.astrodon.com

X-Y Guidestar Finder

Orion Telescopes & Binoculars
Watsonville, California

Orion's X-Y Guidestar Finder eliminates the need for astroimagers to move the guiding telescope. The 1¼" barrel fits standard focusers. The X-Y fine-adjustment knobs move the autoguider up to 1.1 inches (28mm) to bring more stars into view.

Price: $189.95
[t] 800.447.1001
[w] www.telescope.com

40mm eyepiece

Smart Astronomy
Staten Island, New York

Smart Astronomy's 2" Sterling Series 40mm Plössl eyepiece offers a 55° apparent field of view. It has 40 layers of coatings that allow 98 percent of the light to pass through. A threaded barrel accepts 2" filters. The eyepiece weighs 13.6 ounces (387g).

Price: $99.95
[t] 888.291.6577
[w] www.smartastronomy.com

70mm portable telescope

Celestron
Torrance, California

Celestron's Travel Scope 70 features a 2.76-inch refractor with a focal ratio of f/5.71. The telescope comes with an aluminum tripod, 20mm (20x) and 10mm (40x) eyepieces, an erect-image diagonal, and a 5x24 finder scope. It all fits into the Travel Scope's custom backpack.

Price: $99.95
[t] 310.328.9560
[w] www.celestron.com

Piggyback mount for cameras

Celestron
Torrance, California

Celestron's Piggyback Mount allows astroimagers to attach a camera to the top of the telescope. That makes it possible to shoot with a normal or wide-angle lens while guiding through the telescope. The Piggyback adapter mounts to the rear cell of the C8, C9.25, C11, and C14 telescopes.

Price: $51.99
[t] 310.328.9560
[w] www.celestron.com

Attention manufacturers: To submit a product for this page, e-mail **mbakich@Astronomy.com.**

APM ■ TAKAHASHI ■ MEADE ■ ORION OPTICS UK ■ TELESKOP-SERVICE ■ ASTROSIB

APM America TELESCOPES

BRINGING **QUALITY** CLOSER TO HOME

973-406-4060 www.apmamerica.com

NORMAND FULLUM TELESCOPES ■ & MORE... Plus a full line of visual and imaging accessories

STELLARVUE®

SEEING IS BELIEVING

NEW CARBON FIBER LIGHTWEIGHT ED REFRACTORS

80 MM, 90 MM, 105 MM GRAB AND GO APO TRIPLETS

NEW 130 MM APO TRIPLET ALUMINUM AND CARBON FIBER

STELLARVUE®

FROM DREAM TO REALITY

SV105 image of Comet Lulin by Jon Talbot

STELLARVUE®

WWW.STELLARVUE.COM

11820 KEMPER ROAD

AUBURN, CA 95603

(530) 823-7796

New Mexico Skies Astronomy Enclave

Where the "SEEING" is BELIEVING!™

- **A limited number of fully improved, mountain top, 2 to 6+ acre Home and Observatory sites with spectacular views, DAY & NIGHT!**
- NM Skies is the premiere **mountain-top** amateur astronomy community. With underground electric, high speed internet, community-wide water & great neighbors, **we're ready for your home & observatory!**
- **Club House & Community Machine Shop coming soon!**
- A micro-climate second to none gives NM Skies excellent seeing, great transparency, moderate winds, and year 'round comfortable temperatures.
- **EXTREMELY DARK SKIES** with strict light pollution rules and astronomy friendly deed restrictions. Plus, being surrounded by the Lincoln National Forest assures us of exceptionally dark skies for generations to come.

www.NMSouthernSkies.com

1-877- 4-GR8-SKY Tom Simstad

The Astro-Tech 8" f/4 imaging Newtonian is a steal at $449.

The **Astro-Tech AT8IN** is a very fast focal ratio (f/4!) 8" reflector that has been optimized for superior high-contrast wide field deep space imaging.

The optical tube has been extended forward of the focuser to act as a lens shade. Then, 17 internal knife-edge baffles in the optical tube eliminate any minor stray light that might get past the tube extension. The result is contrast far better than a conventional reflector, both when imaging *and* viewing.

The Astro-Tech AT8IN comes with a built-in cooling fan, a 2" dual-speed Crayford focuser with 2" and 1.25" compression ring accessory adapters, an 8 x 50mm finderscope in a quick-release bracket, and dual split mounting rings. An optional coma corrector is available.

An Astro-Tech field flattener is only $150. Why do others cost so much more?

The **Astro-Tech AT2FF** 2" zero-power field flattener for f/6 to f/8 refractors corrects the curved field every doublet or triplet refractor exhibits in photos. You get point-like stars across the entire field – for only a fraction the cost of competitive field flatteners. As always, you get more performance than you pay for with Astro-Tech. Multicoated, with a 2" barrel on one side and T-threads on the other.

ASTRO-TECH from **Astronomy Technologies**
680 24th Avenue SW, Norman, OK 73069

Astro-Tech is available at these U. S. dealers: **astronomics.com ● highpointscientific.com ● starizona.com auroraastro.com ● greatredspot.com ● sunrivernaturecenter.org ● camerabug.com**

In Canada, Astro-Tech is available **escience.ca**, and in Europe at these dealers: **altairastro.com locascope.com ● scsastro.co.uk ● robtics.nl ● aleph-lab.com**

All prices plus freight.

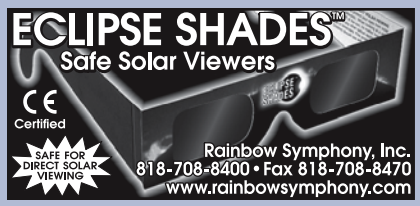
Dealer inquiries: info@astronomytechnologies.com

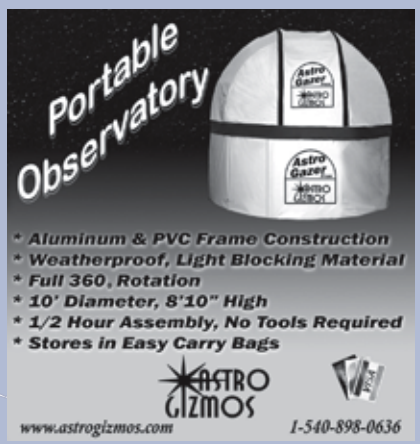
MARKETPLACE

Khan Scope Centre

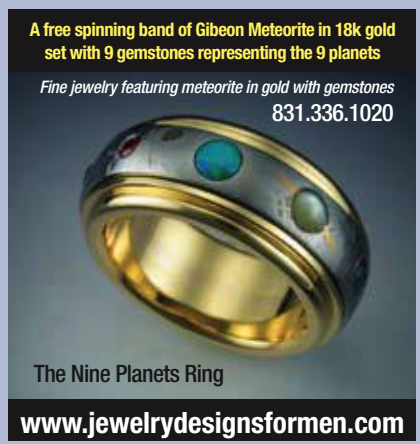
ScopeStuff
Telescope Accessories & Hardware
www.scopestuff.com
512-259-9778

AstroMart
Used Telescopes
www.astromart.com





bigbinoculars.com
Astronomical binoculars and accessories at down-to-earth prices. Visit our online store at www.bigbinoculars.com or call toll-free from 9:00 to 5:00 (EDT) 866-244-2460.
OBERWERK BT-100-45
FUJINON MIYAUCHI OBERWERK


A free spinning band of Gibeon Meteorite in 18k gold set with 9 gemstones representing the 9 planets
Fine jewelry featuring meteorite in gold with gemstones
831.336.1020
The Nine Planets Ring
www.jewelrydesignsformen.com

ASTRO-PHYSICS
Experience the ultimate in quality instruments for discriminating observers and astrophotographers.
Telescopes, Go-To German Equatorials, Visual and Photographic Accessories
Unparalleled Service and Support
Experience the legend that is ASTRO-PHYSICS!
160mm f7.5 StarFire EDF
900GTO
11250 Forest Hills Road
Machesney Park, IL 61115, USA
Ph: 815-282-1513, Fax: 815-282-9847
www.astro-physics.com

The Most Complete Telescope Store in Texas
Authorized dealer:
Celestron, Orion, Tele Vue, Meade, Vixen, Fujinon, Vortex, Home-Dome, Books, Charts, Software
Service • Repairs
Private lessons
FREE instruction at night with every telescope purchase
THE OBSERVATORY
The Observatory, Inc.
17390 Preston Road #370
(Two traffic lights north of Campbell Rd.)
Dallas, TX 75252 (972) 248-1450
www.TheObservatoryInc.com

"New astronomical atlases, up to 900 maps and 16th magnitude"
www.jviewbook.com
J-VIEW BOOK
J-View Book® the most innovative Atlases for High Tech era

ScopeBuggy

- For use with most tripods, DOBs and piers
- 10" Pneumatic tires for soft ride

$295.00
Plus S&H
Approx. $30 Shipping
USA

SCOPEBUGGY
P.O. BOX 834
Elephant Butte, NM
87935

Toll Free: 866-312-8449
www.scopebuggy.com

OMI
OPTICAL MECHANICS, INC.
• Mirror Coating Service
• Telescope Mirrors
• Cassegrain Telescopes
www.opticalmechanics.com
319.351.3960

PEGASUS OPTICS - Mirrors
★ Wavefront P-V <1/8 wave ★ 1.6 -2" thick ★IAD Coating

Dia.	FL	Price	Dia.	FL	Price
18"	75.6"	$2800	22"	100"	$5000
20"	90"	$3600	24"	110"	$6600

"You'll see the difference"
Web Site: PegasusOptics.Com E-mail: hallj@satx.rr.com
TEL: (210) 267-9937

Space Law Academy
Attention Citizens of Planet Earth!
New Distance Learning Course
Introduction to Space Law
www.SpaceLawAcademy.com

Optical Coatings
Parabolic Mirrors
Testing
Refiguring
www.OpticWaveLabs.com

TRACKING for DOBS
* High power observing and group viewing
*Astro-imaging with NO field rotation
call write or e-mail for free brochure
EQUATORIAL PLATFORMS 530-274-9113
15736 McQuiston Lane Grass Valley CA 95945
tomosy@nccn.net www.equatorialplatforms.com

BUY DIRECT AND SAVE
152 mm f-5.9

WWW.ASTROTELESCOPES.COM

THE WORLD'S BEST FILTERS AND ASTRONOMICAL ACCESSORIES

PREMIUM QUALITY FILTERS

THE DEEP SKY FILTER The BEST light pollution filter on the market today! Perfect for visual and photographic use.
1.25" - $99.95 • 2" - $199.95
Cassegrain Rear Cell - $199.95

THE ULTRA HIGH CONTRAST FILTER The ULTIMATE dark sky nebula filter. Reveals the faintest of objects under both light polluted and dark skies.
1.25" - $99.95 • 2" - $199.95
Cassegrain Rear Cell - $199.95

THE OXYGEN III FILTER Legendary performance allowing near photographic views of diffuse, planetary and extremely faint nebulae.
1.25" - $99.95 • 2" - $199.95
Cassegrain Rear Cell - $199.95

THE HYDROGEN-BETA FILTER View extremely faint objects such as the Horsehead and California Nebulae. Ideal for use with 8" and larger telescopes.
1.25" - $99.95 • 2" - $199.95
Cassegrain Rear Cell - $199.95

THE NIGHT SKY HYDROGEN-ALPHA FILTER A powerful photographic aid in over-coming light pollution during astrophotography of faint emission nebulae.
Various sizes starting at $79.95

THE MINUS VIOLET FILTER Produce pinpoint stars and greatly improve imaging by reducing chromatic aberration in lens systems.
1.25" - $59.95 • 2" - $79.95
58mm - $89.95 • 72mm - $99.95

THE POLARIZING FILTER Reduce glare and increase contrast on the moon and planets, as well as daytime objects. Also available in variable polarizing designs.
Single 1.25" - $29.95 • 2" - $39.95
Variable 1.25" - $39.95 • 2" - $49.95

THE INFRARED BLOCKING FILTER LUMICON'S IR Blocking Filter is used for visible spectrum (RGB) astrophotography with cameras and CCD equipment. 1.25" - $69.95 • 2" - $99.95

LUNAR AND PLANETARY FILTERS For increased contrast on Lunar and planetary details. Optimized for both visual and photographic applications. Visit www.lumicon.com for uses.
1.25" - $19.95 • 2" - $29.95

MULTIPLE FILTER SELECTORS Switch back-and-forth between filters without having to thread and unthread them from your eyepieces or diagonal. Leaving one of the slots open lets you compare views with and without your LUMICON filters. Made from solid aircraft aluminum. *(Filters Sold Separately)* 1.25" - $129.95
2" - $169.95 • T-Thread Adapter for 2" - $24.95

Visit **LUMICON.COM** for a complete list of Superior Quality Astronomical Accessories and Photographic Equipment. TO ORDER: please call us or visit our website for a complete list of Authorized Lumicon Dealers worldwide. *Prices do not include shipping and handling or state taxes where applicable.*

LUMICON
750 Easy St., Simi Valley, CA 93065 • US 800.420.0255 • 805.520.0047
WWW.LUMICON.COM

Howie Glatter's Lasers
Collimators & Accessories: Shockproof-Individually Tested
Hand Machined to < 0.0002" < 15 arc sec.beam alignment
The original self-Barlow attachment
The Blug® Barlowed Laser Plug (pat. pend.)
NEW! tuBlug® Alignment Tool

Intelligent Design ?

Or just the natural evolution of Nils Olof Carlin's Barlowed laser method ?

You are invited to join the search for an answer

Howie Glatter 3850 Sedgwick Ave. Bronx, N.Y. 10463
Tel/Fax (718) 796 3203
www.skypointer.net www.collimator.com
e-mail: howieglatter@mindspring.com

Astronomer's Source for Astro-Imaging

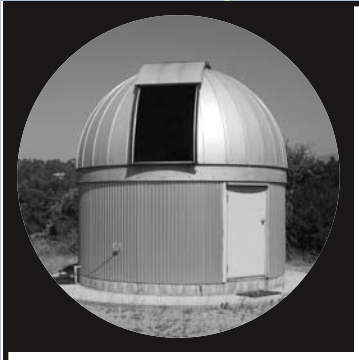
The BEST CCD Cameras from QSI, ATIK, Imaging Source, Lumenera, Orion, SBIG, & Starlight Xpress.

Astrovid Video Cameras; AllSkyCam, FireballCam, Wireless StellaCam3, & PlanetCam

REAL SCIENCE with the Lhires III & Lhires Lite Spectrographs. AstroDon, & Optec Photometric Filters

Many more innovative imaging products, accessories, expert advice, & excellent service at:

toll-free 877-348-8433
outside USA 518-747-4141
www.astrovid.com
ADIRONDACK Astronomy



FOCUS ON
The Webb Schools
Tularcitos Observatory, Carmel Valley, CA

The Ash-Dome houses a Losmandy G-11 equatorial mount with interchangeable Celestron 8.5 inch and 14 inch telescopes. Adjacent to the observatory is a giant armillary hemisphere. The astronomy program includes credit coursework as well as outreach programs to the surrounding community. Open observatory nights are a regular part of the science program at this college-preparatory boarding school. A unique feature of this observatory is a second level floor allowing the use of the telescopes without ladders.

ASH MANUFACTURING COMPANY
P.O. Box 312
Plainfield, IL USA 60544
815.436.9403 • FAX 815.436.1032
web site: www.ashdome.com
email: ashdome@ameritech.net

Major astronomical groups, amateurs, universities, colleges, secondary & primary schools recognize ASH-DOME internationally for their performance durability and dependability. Standard sizes from 8 to 30 feet in diameter. Brochures and specifications available.

MARKETPLACE

Green Star-Pointing Laser
- Visible Beam
- Full 5mw Output
- Free Shipping
- Higher Outputs Available

$35•www.maxsontechonline.com

Why view through your scope with ONE EYE when we let you use TWO?!
DENKMEIER
Systems starting at $499
www.denkmeier.com
Toll free: (866) 340-4578

EUROPE'S PREMIER WEBSITE
http://www.scsastro.co.uk
SCS ASTRO

Hate to Rotate?
Discover why our clamshell domes are simply the best solution. (7ft to 20ft Diameter)
949.215.3777
www.ASTROHAVEN.com
domesales@astrohaven.com

Quality Eyepieces / Accessories
Knight OWL
New Products:
Nebula Filters: UHC & O-III
Filter Wheels
Multiple Eyepiece Holder
Great Value and Quality
Call: 1-888-OWL-WARE
www.Owlastronomy.com

Anacortes Telescope
www.buytelescopes.com
800-850-2001

STARIZONA
Let's Talk Stars
www.letstalkstars.com
With your Hosts David and Wendee Levy
Astronomy talk radio

NOT BILLIONS AND BILLIONS BUT
JMI HAS THOUSANDS OF PRODUCTS TO MAXIMIZE YOUR NIGHT LIFE
1 800 247-0304
303 233-5353
jmitelescopes.com

AstroSystems
Telescopes, Telescope Kits, Spiders, Secondary Holders and more.
www.astrosystems.biz

INDEX *of* ADVERTISERS

Adirondack Video Astronomy 67
Adorama 5, 61
Anacortes Telescope & Wild Bird 66, 68
APMAmerica 65
Ash Manufacturing 67
Astro Gizmos 66
Astro Haven 68
Astro-Physics 66
Astronomics 3
Astronomy.com 64
Astronomy magazine 68
Astronomy Sweepstakes 16-17
Astronomy Technologies 65
AstroSystems 68
AstroTelescopes 67
Beam of Light Technologies 66
Celestron 7, 9
Daystar Filters 61
Denkmeier Optical 68
Equatorial Platforms 67
Explore Scientific 13
Glatter Howard 67
J-View Book 66
Jewelry Designs For Men 66
Jim's Mobile, Inc 68
Khan Scope Centre 66
Let's Talk Stars 68
Lumicon 67
Majestic Optical Coatings 66
Maxson Technologies 68
Meade Instruments Corporation 74
My Telescope 53
New Mexico Southern Skies 65
Observatory Inc, The 66
Oceanside Photo & Telescope 53
Optic Wave Laboratories 67
Optical Mechanics, Inc 67
Orion Telescopes & Binoculars 4
Owl Services 68
Pegasus Optics 67
Rainbow Symphony 66
Scope Buggy 67
ScopeStuff 66
SCS Astro 68
Solarscope 66
Space Law Academy 67
Stellarvue 65
Teaching Company, The 23
Technical Innovations 21
Tele Vue Optics, Inc 2
The Mars Society 53
Vixen Optics 73
Woodland Hills Cameras & Telescopes 61
www.bigbinoculars.com 66

The Advertiser Index is provided as a service to *Astronomy* magazine readers. The magazine is not responsible for omissions or for typographical errors in names or page numbers.

NEXT MONTH
in the September issue

Daniel B. Phillips

Astronomy
The world's best-selling astronomy magazine

How Earth sprang to life
At some point in the dim past, inorganic matter started to replicate itself. Scientists are still trying to figure out how.

What revved up the galaxy's fastest stars?
Since 2003 astronomers have found 16 hyperfast stars escaping the Milky Way's gravity. The slingshot could be our galaxy's central black hole.

How astronauts fixed Hubble
During the course of five spacewalks, Atlantis astronauts installed two new instruments and repaired two older ones, making the venerable space telescope the best it's ever been.

The stars that revealed the vastness of the universe
Cepheids are pulsating variable stars that astronomers use to measure cosmic distances. They remain at the heart of solving key cosmic riddles.

Astronomy's 2009 astroimaging contest
Amateurs accepted the challenge and sent us these dazzling images.

10 tips for beginning astroimagers
Use these techniques to produce celestial images you'll be proud to share with friends and family.

SUBSCRIBE TODAY!
1.800.533.6644
ORDER ONLINE AT
Astronomy.com

The Cosmic Grid

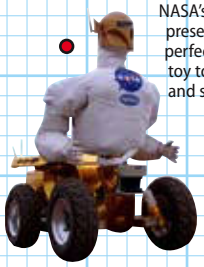
All things high, low, weird, and wonderful in astronomy and space science. **by Daniel Pendick**

WEIRD

HOT

NOT

PREDICTABLE



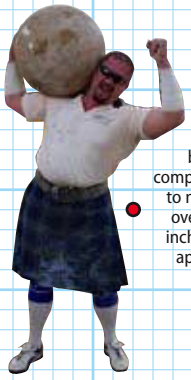
Space centaur
NASA's experimental telepresence Robonaut: the perfect cross-promotion toy to sell Happy Meals and spaceflight to kids!

Cosmic curry
Indian researchers will concoct freeze-dried traditional cuisine to make their astronauts feel more at home in space.

Hang in there, little guy
"Space bat" clings to the main fuel tank of space shuttle Discovery as it launches March 15, 2009. A metaphor for our troubled economic times?

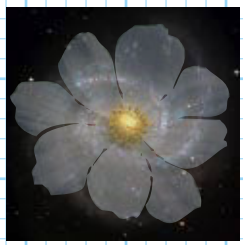
Hold the sunblock
Astrophysicist Paolo Gondolo and colleagues propose an offbeat theory. They think the first suns were "dark stars" composed of dark matter particles.

Cheap speed
Researchers network 16 PlayStation 3 game consoles to simulate black-hole vibrations. The "PS3 Gravity Grid" also runs Street Fighter IV at wicked-fast speed.



World's strongest astronomer
When not hefting 340-pound (153 kg) stone balls, former strongman competitor Mike Sidonio likes to notch deep-sky objects over Australia with his 6-inch Astro-Physics StarFire apochromatic refractor.

Poetic license
"The magnetic field of a star is, like the scent of a flower, subtle and invisible, but it plays an essential role in evolution." — Andre Maeder, et al., *Cosmic Magnetic Fields: from Planets to Stars and Galaxies.* Proceedings IAU Symposium No. 259, 2009



Colbert — not!
TV host Stephen Colbert fails in his attempt to name a new segment of the space station after himself.

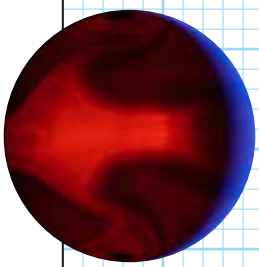
Hey good looking!
BBC Online dubs the slender, shapely, silvery, sexy GOCE geophysical observatory the "supermodel" of satellites.

Pluto's got a friend in Illinois
The Illinois Senate votes unanimously to grant Pluto full planetary status as it "passes overhead through Illinois' night skies."

Astronomical increase
NASA estimates the cost to regain an ability to launch astronauts after the shuttle retires at (gulp) $44 billion.

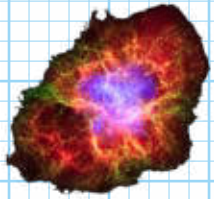
Shaky science
A study finds that the space elevator, thought for decades to be the only technology for breaking Earth's gravitational grip cheaply, would wiggle erratically upon use. Now I'll never get off this rock!

Orbital accolades
Dutch amateur astronomer Ralf Vandebergh images a spacewalking astronaut on the space station through his 10-inch Newtonian telescope. Nice shot!

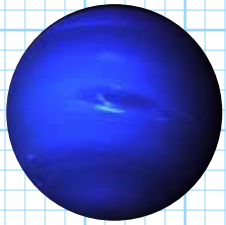


Short summer
The extreme seasonal swings on extrasolar planet HD 80606b: a few hours of sizzling summer followed by 111 days of winter.

Trust me on this one
The world will not end in 2012 with the turnover in the Mayan calendar. No, really. It really, really won't.



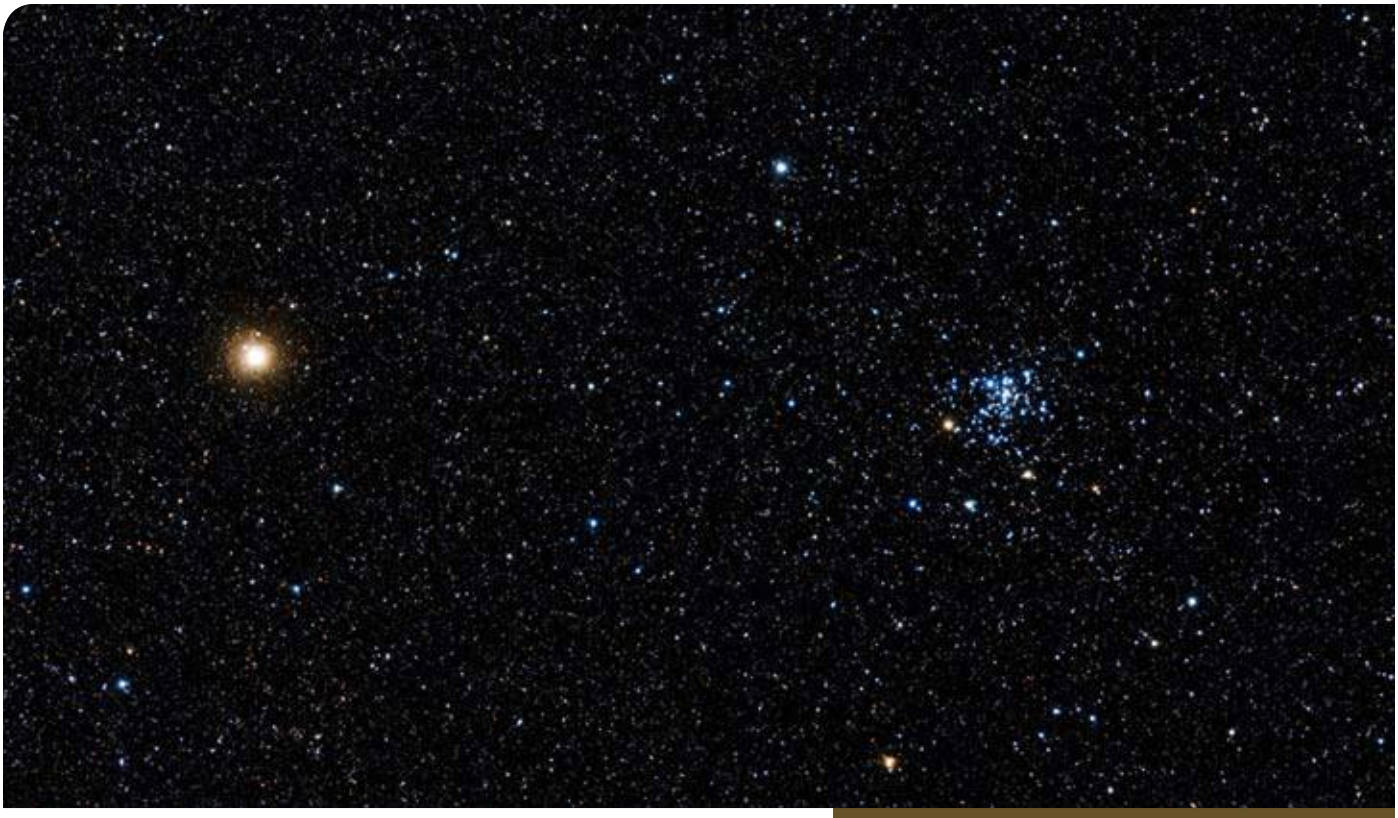
Cool blast
Japanese researchers uncover a possible chemical trace of the 1054 supernova that created the Crab Nebula — in Antarctic ice.



Galileo who?
73% of people polled in the United Kingdom credit Galileo with discovering Neptune. And Isaac Newton discovered apples, right?

Photographs: NASA (space centaur); *Astronomy*: William Zuback & Chuck Braasch (curry); *Astronomy*: William Zuback (PlayStation); Mike Sidnio (strongman); NASA (space bat); NASA/SOHO (sunblock); Curt and Sally King/Adam Block/NOAO/AURA/NSF (poetic license); Martin Crook (Colbert); NASA/ Pat Rawlings (space elevator); NASA (Ares rocket); NASA/JPL (Neptune); NASA/ESA/CXC/JPL-Caltech/ASU/UM/STScI (Crab Nebula); NASA/JPL-Caltech/UCSC (HD 80606b); Ralf Vandebergh (spacewalk); ESA (GOCE)

reader gallery

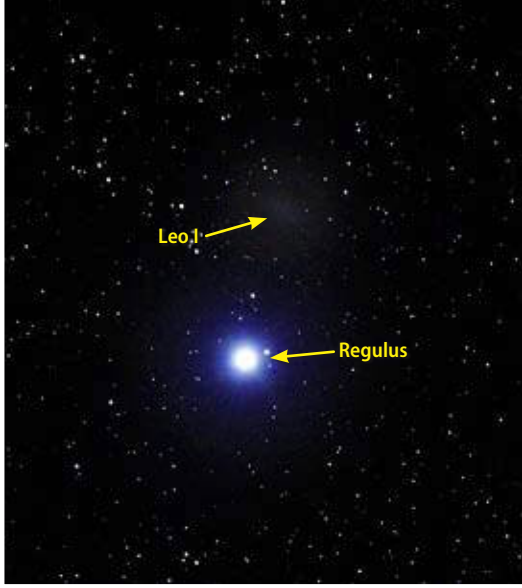


Open cluster NGC 2516 (Canon 400D digital SLR, Canon 200mm lens at f/2.8, ISO 1600, 40-minute exposure) • Yuri Beletsky, Santiago, Chile

Spiral galaxy M101 looks impressive, but it can be a disappointing view through small telescopes. M101's magnitude 7.9 brilliance spreads over a 22'-diameter area. (12.5-inch RC Optical Systems Ritchey-Chrétien telescope at f/9, SBIG ST-11000 CCD camera, LRGB image with exposures of 60, 10, 10, and 10 minutes, respectively) • Richard Jacobs and Frank Martin, Chandler, Arizona

Scanning the southern sky

Open cluster NGC 2516 in the southern constellation Carina the Keel lies 3.3° west-southwest of magnitude 1.9 Avior (Epsilon [ε] Carinae). Together, the magnitude 3.8 open cluster and the star make a pretty pair. At those magnitudes, Avior shines more than 6 times brighter than the cluster. Avior is a double star whose brighter component is a cool red giant star. An extremely hot blue Sun-sized star orbits the primary. Astronomer Yuri Beletsky of the European Southern Observatory took this shot under a dark sky in the Chilean Andes.



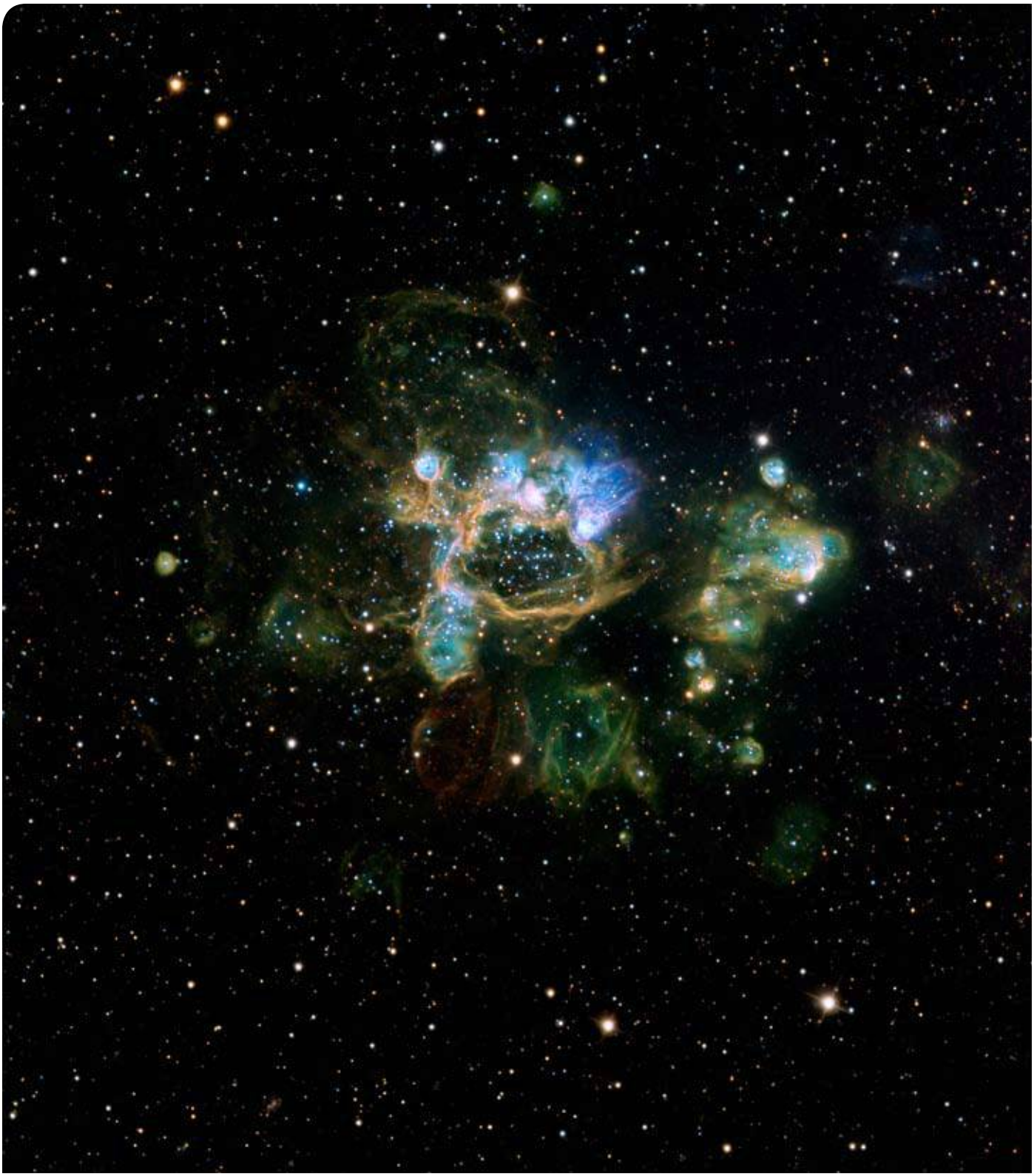
∧ Dwarf galaxy Leo I's visual magnitude (9.8) is bright as galaxies go. Its light, however, spreads over an area measuring 11.4' by 8.7' — 14 percent of the Full Moon's size. You'll need at least an 8-inch scope and a dark sky to see this galaxy. What makes this galaxy both easy and difficult to locate is its position, only 20' north of Regulus (Alpha [α] Leonis). (3.2-inch Stellarvue SV80S refractor with 0.8x field flattener for f/4.74, Canon 10D digital SLR, ISO 800, 30-minute exposure) • Chris Schur, Payson, Arizona

< Emission nebula Cederblad 214 and open cluster NGC 7822 create a cosmic wreath in Cepheus. (5-inch Tele Vue 127is, Apogee U9000 CCD camera, 14 hours of Hα images combined, plus 7.2-inch Takahashi 180, Apogee U9 CCD camera, 11 hours total exposure time through red, green, and blue filters) • Adam Block and Tim Puckett, Ellijay, Georgia

> Orion the Hunter sets behind the telescope domes of the W. M. Keck Observatory, which stands 13,796 feet (4,205 meters) above sea level atop Hawaii's Mauna Kea volcano. The night sky's brightest star, Sirius (Alpha [α] Canis Majoris), shines at the upper left. (Canon EOS Rebel digital SLR, 18-55mm lens set at 18mm and f/5.6, ISO 800, 30-second exposure, taken April 15, 2006, at 9:17 P.M. Hawaiian Standard Time) • Ralph Ford, Redondo Beach, California

reader gallery

Send your images to: *Astronomy* Reader Gallery, P. O. Box 1612, Waukesha, WI 53187. Please include the date and location of the image and complete photo data: telescope, camera, and exposure information. Submit images by e-mail to readergallery@Astronomy.com.



Emission nebula N44 in the Large Magellanic Cloud (a satellite galaxy of the Milky Way) lies about 170,000 light-years away. The normally red object appears different in this false-color image. The "hole" in the center spans some 250 light-years. Massive stars within the nebula have pushed out much of the glowing gas in that region. (12.5-inch RC Optical Systems Ritchey-Chrétien telescope at f/9, Apogee Instruments U16M CCD camera, Astrodon narrowband filters, Hα/OIII/SII image with exposures of 4, 3.5, and 0.5 hours, respectively) • Don Goldman, Orangevale, California

Vixen Proudly Introduces....

PORTA II MOUNT

The next generation of Porta with removable head and flexible slow motion handles.

NEW DUAL SPEED FOCUSER

Standard on the ED81S, ED103S, ED115S, NA140SSf, and the NEW AX103S. Can be installed on your R200SS, VMC200l and VC200L.

When You are ready for something Better....

Vixen Optics

A Division of MrStarGuy, Inc

Visit our Premiere Dealers

- Woodland Hills (888) 427-8766-www.telescopes.net
- Smart Astronomy (888) 291-6577-www.smartastronomy.com
- Boots Camera-Fresno, CA (559) 432-0446
- Scope City (800) 235-3344- www.scopecity.com
- Hands on Optics-Damascus, MD (301) 482-00002
- OPT (800) 483-6287-www.optcorp.com
- Telescopes.com (800) 303-5873-www.telescopes.com
- Camera Bug-Atlanta, GA (404) 873-4513
- Adorama (800) 223-2500 - www.adorama.com
- Stargate Astronomy-Colorado Springs, CO (719) 339-4456

www.vixenoptics.com

THIS CHANGES EVERYTHING

THE NEW ETX-LS® WITH LIGHTSWITCH™ TECHNOLOGY. BRINGING THE FUN BACK TO ASTRONOMY.

Meade takes out all the hassles and puts in all the fun with the all-new ETX-LS featuring LightSwitch technology. Now it's fast and easy to perform all start-up functions with just a flip of the switch. The revolutionary LightSwitch technology automatically delivers telescope location, time, date, orientation and alignment with the sky – all with a single touch. And thanks to Meade's exclusive Advanced Coma-Free™ optics, you see it all in stunning Ritchey-Chrétien-like clarity. And with the Astronomer Inside™ comprehensive multi-media content, you experience the universe in a way you never have before. In short, the ETX-LS incorporates everything you've come to expect from Meade, the undisputed leader in innovation and quality.

Just look at all these radically new, cutting-edge features:

LIGHTSWITCH TECHNOLOGY FOR EASY, AUTOMATIC SELF-ALIGNMENT

Meade's patented automatic self-alignment system – just one touch and it does all of the work for you. No stars to center. No bearings to take. No time or location to enter. Just flip the switch.

MEADE'S ASTRONOMER INSIDE

Take a multi-media guided tour of the universe, or select your favorite object and the ETX-LS' Astronomer Inside gives you fun and informative audio descriptions of over 500 objects while you view them in the eyepiece – or experience the whole dazzling multi-media presentation on an attached video monitor* – complete with audio, video, still images and text.

ACF™ (ADVANCED COMA-FREE™) OPTICS – SHARP, CLEAR, BRILLIANT

Meade's proprietary, Advanced Coma-Free optics will wow you at first sight. Distortion-free clarity. Sharp-as-a-tack resolution. ACF's state-of-the-art optics are so good, you'll see more objects than you've ever thought possible. Just compare ACF to Ritchey-Chrétien systems selling for $10,000 or more, and ACF's quality will absolutely astound you. Also available with Meade's premium low-cost Schmidt-Cassegrain optics.

BUILT-IN IMAGING EXCITEMENT

The built-in ECLIPS CCD lets you capture wide-field images of constellations, star fields and display them in real-time* or save them to an SD card, with no external computer needed.

So drop by your nearest Meade dealer, or give us a visit at www.meade.com to learn more about the exciting new ETX-LS – the hassle-free telescope that makes viewing the heavens fun again. Only from Meade.

©2009 Meade Instruments Corporation. All rights reserved. Specification subject to change without notice. 30-09003

Telescopes.com	OPT Telescopes	Optics Planet	Woodland Hills	Astronomics	Focus Camera	Canada • Kahn Scopes
800.303.5873	800.483.6287	800.504.5897	888.427.8766	800.422.7876	800.221.0828	800.580.7160

6" ETX-LS® – focal length 1524mm / f10 – ACF-$1499. SC-$1299.

*Requires external video monitor, not included.

MEADE